# Bengaluru Smart Infrastructure Limited (B-SMILE)

## International Competitive Bidding under

## Single-Stage Two Envelope

## Bidding Process

## for

## Design and Construction of 3-Lane Underground Twin Tunnel Road from Hebbal Esteem Mall junction (Km. 0+000) to Silk Board KSRP Junction (Km.16+745) along with 3-lane/2-lane entry & exit ramps including operation and maintenance in Bengaluru City (North South Corridor) – on MODIFIED BOOT MODE.
## PACKAGE-2: SESHADRI ROAD (KM 8.748) TO SILK BOARD (KM 16.745).

# TECHNICAL SCHEDULES TO CONCESSION AGREEMENT

(Schedules A to D)

## VOLUME -3 A

June 2025

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# SCHEDULE - A

## Schedule - A

(See Clause 10.1)

## SITE OF THE PROJECT TUNNEL

### 1. The Site

1.1 Site of the Project Tunnel shall include the land, buildings, Structures and road works as described in Annex-I of this Schedule-A. The dates of handing over the Right of Way to the Concessionaire are specified in Annex-II of this Schedule-A. The alignment plans of the urban roads are specified in Annex-III. The Concessionaire, however, may improve/upgrade based on site/design requirements with prior approval from IE and Authority. An Index Map of the Project is given in **Appendix A-I,** Center line coordinates of Tunnel Tubes and ramps are given in Appendix – AII.

1.2 An inventory of the Site including the land, buildings, Structures, road works, trees and any other immovable property on, or attached to, the Site shall be prepared jointly by the Authority Representative and the Concessionaire, and such inventory shall form part of the memorandum referred to in Clause 10.3.1 of this Agreement.

1.3 Additional land required for construction of works specified in the Change of Scope Order issued under Clause 16.2.3 of this Agreement shall be acquired in accordance with the provisions of Clause 10.3.6 of this Agreement. Upon acquisition, such land shall form part of the Site and vest in the Authority.

1.4 The Project is exempt from Environmental Clearance as per the document produced in Schedule A Annex-vi

**Annex – I**

(Schedule-A)

## 1 The Site

The site of Vehicular Underground 3-lane Twin Tunnel Road for the North-South Corridor of Bengaluru between Seshadri Road, Freedom Park (Km 8+748) to Silk Board (Km 16+745) along with 3-lane & 2-lane entry & exit ramps is located in Bengaluru in the state of Karnataka.

An Index Map of the Project is given in **Appendix A-I** and the alignment plan is provided in **Annex-III.**

The start and end chainage coordinates of the package are given below:

| S. No. | Easting | Northing | Remarks |
|---|---|---|---|
| 1 | 780055.550 | 1436470.791 | Start Point of Main Tunnel |
| 2 | 783915.714 | 1430564.140 | End Point of Main Tunnel |

## 2 Land

The Site of Carriageway and structures comprising the land (existing Right of Way) as described below:

| Ramp/Tube | Chainage | | Length | EROW | Additional Right of Way (m) | PROW |
|---|---|---|---|---|---|---|
| | From | To | | in (m) | | |
| Entry Ramp-5 | -217 | 0 | 217 | 28 | *4.75* | 32.75 |
| | 0+000 | 0+100 | 100 | 26 | *5* | 31.00 |
| | 0+100 | 0+185 | 85 | 12 to 25 | *9* | 33.50 |
| | 0+185 | 0+270 | 85 | 12 to 18 | *9 to 18* | 39.00 |
| Entry Ramp-6 | 0+000 | 0+150 | 150 | 22 to 27 | *0* | 35.50 |
| | 0+150 | 0+270 | 120 | 12 to 18 | *0* | 21.00 |
| Exit Ramp-2 | 0+900 | 1+083 | 183 | 23 to 28.97 | *11 to 20.75* | 58.86 |
| | 1+083 | 1+250 | 167 | 28.97 to 39. | *0 to 11* | 53.97 |
| Entry Ramp -7 | 0 | 0+22 | -22 | 18.39 | *0 to 8* | 13.20 |
| | 0+000 | 0+135 | 135 | 17 to 20 | *12 to 15* | 46.50 |
| | 0+135 | 0+250 | 115 | 17 to 18 | *5 to 11* | 36.50 |
| | 0+250 | 0+415 | 165 | 17 | *5 to 20.75* | 32.38 |
| Exit Ramp-1 | 0+000 | 0+050 | 50 | 0 | *0 to 20* | 10.00 |
| | 0+050 | 0+150 | 100 | 16 | *20* | 36.00 |
| Entry Ramp -8 | 0+000 | 0+180 | 180 | 0 | *15* | 15.00 |
| | 0+180 | 0+275 | 95 | 0 | *3 to 15* | 10.50 |
| | 0+275 | 0+350 | 75 | 34 | *0* | 34.00 |
| | 0+350 | 0+556 | 206 | 0 | *20* | 20.00 |
| | 0+556 | 0+654 | 98 | 67 | *0* | 67.00 |
| | ***Common to Tube-1 and Tube-2*** | | | | | |
| Tube-1 and Tube-2 | 16100 | 16400 | 300 | 0 | *40* | 40.00 |
| | 16+400 | 16+500 | 100 | 0 | *15* | 15.00 |
| | 16+500 | 16+600 | 100 | 34 | *11* | 45.00 |
| | 16+600 | 16+745 | 145 | 51 | *11* | 62.00 |
| | 16+745 | 16+910 | 165 | 40 | *0 to 11* | 45.50 |

## 3 Carriageway

The existing road infrastructure includes lane configurations of 4 lanes, and 6 lanes in various segments. The road stretches and lane details included in Package-1 are as follows:

| S.No | Stretch | Lane Configuration |
|---|---|---|
| 1 | Chalukya to Lalbagh botanical garden | 4 lanes |
| 2 | Lalbagh botanical garden to silk board | 4 lanes |
| 3 | KG Marg (Entry Ramp 05 & Entry Ramp-06) | 2 lanes & 6 lane |

| S.No | Stretch | Lane Configuration |
|---|---|---|
| 4 | Sheshadari Road (Exit Ramp 03 & Exit Ramp-04) | 4 lanes |
| 5 | Siddapura Road Entry Ramp 07 from Ashoka Pillar side | 4 lanes |
| 6 | Siddapura Road (Exit Ramp 02 towards Wilson Garden) | 4 lanes |
| 7 | Hosur Road near Silk Board (Exit and Entry of Main Tunnel) | 4 lanes |
| 8 | Sarjapur Road (Entry ramp 08 & Exit ramp 01) | 4 lane with SR |

## 4 Existing Metro Routes

Metro routes cross the project tunnel as mentioned below.

| SI. No | Chainage of proposed alignment | Type of Proposed Structure | Metro Alignment (Elevated/UG) | Remarks |
|---|---|---|---|---|
| 1 | Tube-1 (Ch9+635) and tube-2 (Ch 9+610) | Tube-1 and Tube-2 | Phase-1 | |
| 2 | Tube-1 (Ch9+635) and tube-2 (Ch 9+610) | Tube-1 (Ch 9+635) and tube-2 (Ch 9+610) | Phase-1 | |
| 3 | Tube-1 (Ch 14+600) and Tube-2 (Ch14+622) | Main tunnel tube | Phase-2 | |
| 4 | Exit-1 (Ch 0+160) | Exit-1 | Phase-3a | |
| 5 | Entry ramp -8 (Ch 0+550) | Entry ramp -8 (Ch 0+550) | Phase-3a | |

| SI. No | Chainage of proposed alignment | Type of Proposed Structure | Metro Alignment (Elevated/UG) | Remarks |
|---|---|---|---|---|
| 1 | Km 9.625 to Km.9.645 | Main Tunnel Tube | Metro Phase 1 (UG) | |
| 2 | Km 9.600 to Km.9.620 | Main Tunnel Tube | Metro Phase 1 (UG) | |
| 3 | Km 0.820 to km 0.840 (Entry ramp 5) | Entry Ramp 5 | Metro Phase 1 (UG) | |
| 4 | Km 0.705 to km 0.725 (Entry ramp 6 | Entry Ramp 6 | Metro Phase 1 (UG) | |
| 5 | Km 14.587 to km 14.612 | Main Tunnel Tube | Metro Phase 2 (UG) | |
| 6 | Km 14.610 to km 14.635 | Main Tunnel Tube | Metro Phase 2 (UG) | |
| 7 | Km 0.130 to 0.175 (Exit 1) at silk board towards Sarjapur Rd., near St. john hospital) | Exit 1 | Metro Phase 3A (UG) | |
| 8 | Km 0.525 to 0.600 (Entry 8) at silk board towards Hebbal from Sarjapur Rd. near john hospital) | Entry 8 | Metro Phase 3A (UG) | |

## 5 Existing Indian Railways and K-Rides

Railway routes run across the project tunnel as mentioned below.

| SI. No | Chainage of proposed alignment | Type of Proposed Structure | K-ride Alignment/ Indian Railway existing line | Remarks |
|---|---|---|---|---|
| | NIL | | | |

## 6 Minor Bridges

The Site includes the following minor bridges:

| Sl. No. | Existing Location | Structure | | | Span Length(m) | Deck Width(m) |
|---|---|---|---|---|---|---|
| | | Foundation | Substructure | Superstructure | | |
| | Nil | | | | | |

## 7 Bus bays / Shelters

The details of Bus shelters on the site are as follows:

| Sl. No. | Proposed alignment Chainage (Km) | Length (m) | Side | Remarks |
|---|---|---|---|---|
| 1 | 1+025 | 22.5 | RHS | Exit Ramp (2) |

## 8 Roadside Drains

The details of roadside drains are as follows:

| Sr. No. | Location | Chainage | | Length | Side | Net Drain length(m) |
|---|---|---|---|---|---|---|
| | | From | To | | | |
| 1 | At Lalbagh-Exit Ramp 2 (Towards Siddapura Road near Wilson Garden) | 0+960 | 1+081 | 121 | RHS | 121 |
| **Total Length(m)** | | | | | | **121** |

## Annex II

## (Schedule-A)

## Dates for providing the Right of Way of Construction Zone

The Authority shall provide the Right of Way not less than 50% (Fifty percent) of the total ROW of Project Tunnel on or before appointed date in compliance to Clause 10.3 of Agreement. Right of Way of Balance length to be provided within 240 days (two hundred and forty days) of Appointed Date.

The dates on which the Authority shall provide Right of Way of Construction Zone to the Contractor on different stretches of the Site are stated below:

| SI. No | Chainage | | Length(m) | EROW Width in (m) | Remarks |
|---|---|---|---|---|---|
| | From | To | | | |
| Entry Ramp-5 | -0+217 | 0+000 | -217 | 28 | Back from chainage Alignment (near junction) |
| | 0+000 | 0+100 | 100 | 26 | |
| | 0+100 | 0+185 | 85 | 12 to 25 | Taper |
| | 0+185 | 0+270 | 85 | 12 to 18 | Taper |
| | 0+270 | 1+198 | 928 | - | |
| Entry Ramp-6 | 0+000 | 0+150 | 150 | 22 to 27 | Taper |
| | 0+150 | 0+270 | 120 | 12 to 18 | Taper |
| | 0+270 | 0+700 | 430 | 20 | |
| | 0+700 | 0+750 | 50 | - | |
| | 0+750 | 0+785 | 35 | 35 | |
| | 0+785 | 0+964 | 179 | - | |
| | 0+964 | 0+981 | 17 | 17 | |
| | 0+981 | 1+350 | 369 | - | |
| | 1+350 | 1+373 | 23 | 16 | |
| | 1+373 | 1+435 | 62 | - | |
| | 1+435 | 1+450 | 15 | 20 | |
| | 1+450 | 1+784 | 334 | - | |
| Exit Ramp-2 | 0+000 | 0+900 | 900 | - | |
| | 0+900 | 1+083 | 183 | 23 to 28.97 | |
| | 1+083 | 1+250 | 167 | 28.97 to 39. | Taper |
| Entry Ramp -7 | 0+000 | 0+135 | 135 | 17 to 20 | |
| | 0+135 | 0+250 | 115 | 17 to 18 | Taper |
| | 0+250 | 0+415 | 165 | 17 | Taper |
| | 0+415 | 1+417 | 1002 | - | |
| Exit Ramp-1 | 0+000 | 0+050 | 50 | - | |
| | 0+050 | 0+150 | 100 | 16 | |
| | 0+150 | 0+455 | 305 | 34 | |
| Entry Ramp -8 | 0+000 | 0+180 | 180 | - | |
| | 0+180 | 0+275 | 95 | - | |
| | 0+275 | 0+350 | 75 | 34 | |
| | 0+350 | 0+556 | 206 | - | |
| | 0+556 | 0+654 | 98 | 67 | |
| **Common to Tube-1 and Tube-2** | | | | | |
| Tube-1 and Tube-2 | 8+748 | 16+525 | 7777 | - | |
| | 16+525 | 16+600 | 75 | 34 | |

| | | | | | |
|---|---|---|---|---|---|
| | 16+600 | 16+700 | 100 | 38 | junction |
| | 16+700 | 16+745 | 45 | 40 | |

| S. No | Chainage | | Length (m) | Area (SQM) |
|---|---|---|---|---|
| | Start | End | | |
| Shaft 3 (Including Development of Intermodal Hubs) | 8+717 | 8+848 | 131 | 13463.885 |
| Shaft 4 (Including Development of Intermodal Hubs) | 12+600 | 12+725 | 125 | 15535.142 |
| Shaft 5 (Including Development of Intermodal Hubs) | 15+935 | 16+100 | 165 | 17099.67 |

| TBM Tunnel | Design Chainage | | Length (m) | EROW in (m) | PROW(m) | Influence zone* |
|---|---|---|---|---|---|---|
| | From | To | | | | |
| Tube I (Underground Tunnel) | 8+848 | 12+625 | 3777 | | | 2.5 D from the centre of each tube |
| | 12+725 | 15+990 | 3265 | | | |
| Tube II (Underground Tunnel) | 8+824 | 12+612 | 3788 | | | |
| | 12+712 | 15+968 | 3256 | | | |

*The influence zone shall be 2.5 D (D means external dia. of proposed Tunnel) from either side of each tube.

| NATM Tunnel | Design Chainage | | Length (m) | EROW in (m) | PROW (m) | Influence zone* |
|---|---|---|---|---|---|---|
| | From | To | | | | |
| Entry Ramp 5 (Towards Hebbal Junction) | 0+270 | 1+197 | 927 | - | - | 2.5 D from the centre of each tube |
| Entry Ramp 6 (Towards Silk Board Junction) | 0+270 | 1+783 | 1513 | - | - | 2.5 D from the centre of each tube |
| Exit Ramp-4 (From Hebbal Towards KR Circle on Seshadri Road) | 0+000 | 0+610 | 610 | - | - | 2.5 D from the centre of each tube |
| Exit Ramp-3 (From Silk Board KR Circle on Seshadri Road) | 0+000 | 0+575 | 575 | - | - | 2.5 D from the centre of each tube |
| Exit Ramp 2 (Towards Siddapura Road near Wilson Garden) | 0+000 | 0+900 | 900 | - | - | 2.5 D from the centre of each tube |
| Entry Ramp 7 (From Siddapura Road near Ashok Pillar) | 0+410 | 1+416 | 1006 | - | - | 2.5 D from the centre of each tube |

*The influence zone shall be 2.5 D (D means external Dia of proposed Tunnel) on either side of each tube

## Annex – III

## *(Schedule-A)*

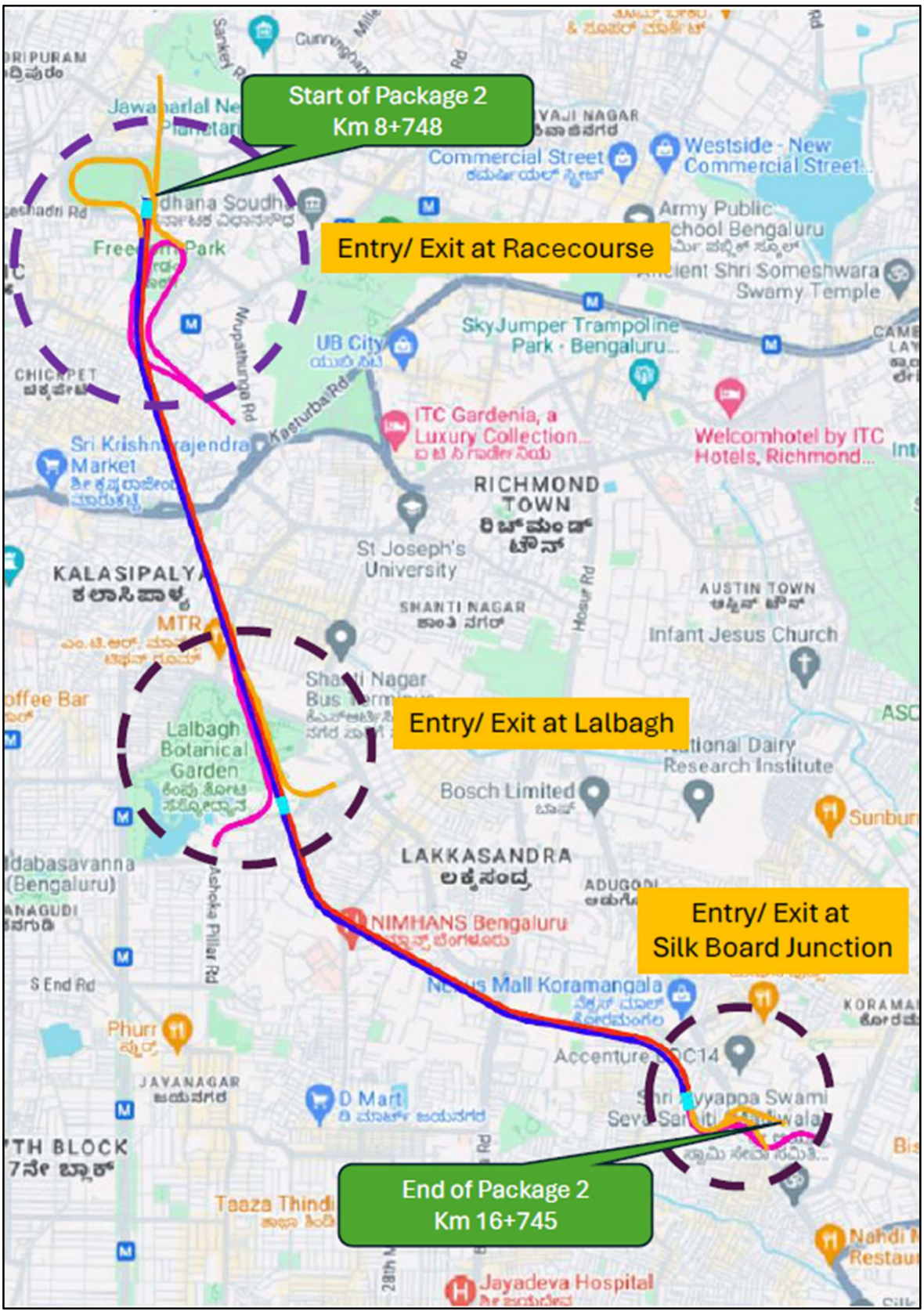
## Alignment Plans

The existing alignment of the urban road shall be modified as per the alignment plan at approach and ramp's location of Project Tunnel. The alignment plan of the Project Tunnel is enclosed in **Appendix B-II**

- The Concessionaire shall, however, improve/upgrade it as indicated in Annex-III based on site/design requirement, within PROW mentioned in clause 2.4 of Schedule B.
- Traffic Signage Plan of the Project Tunnel showing location of traffic signs is enclosed in **Appendix B-V**. The Concessionaire shall, however, improve/upgrade upon the traffic signage plan as indicated based on site/design requirement as per the relevant specifications/IRC Codes/Manual.
- The indicated drainage plan is attached herewith in **Appendix B-III.**

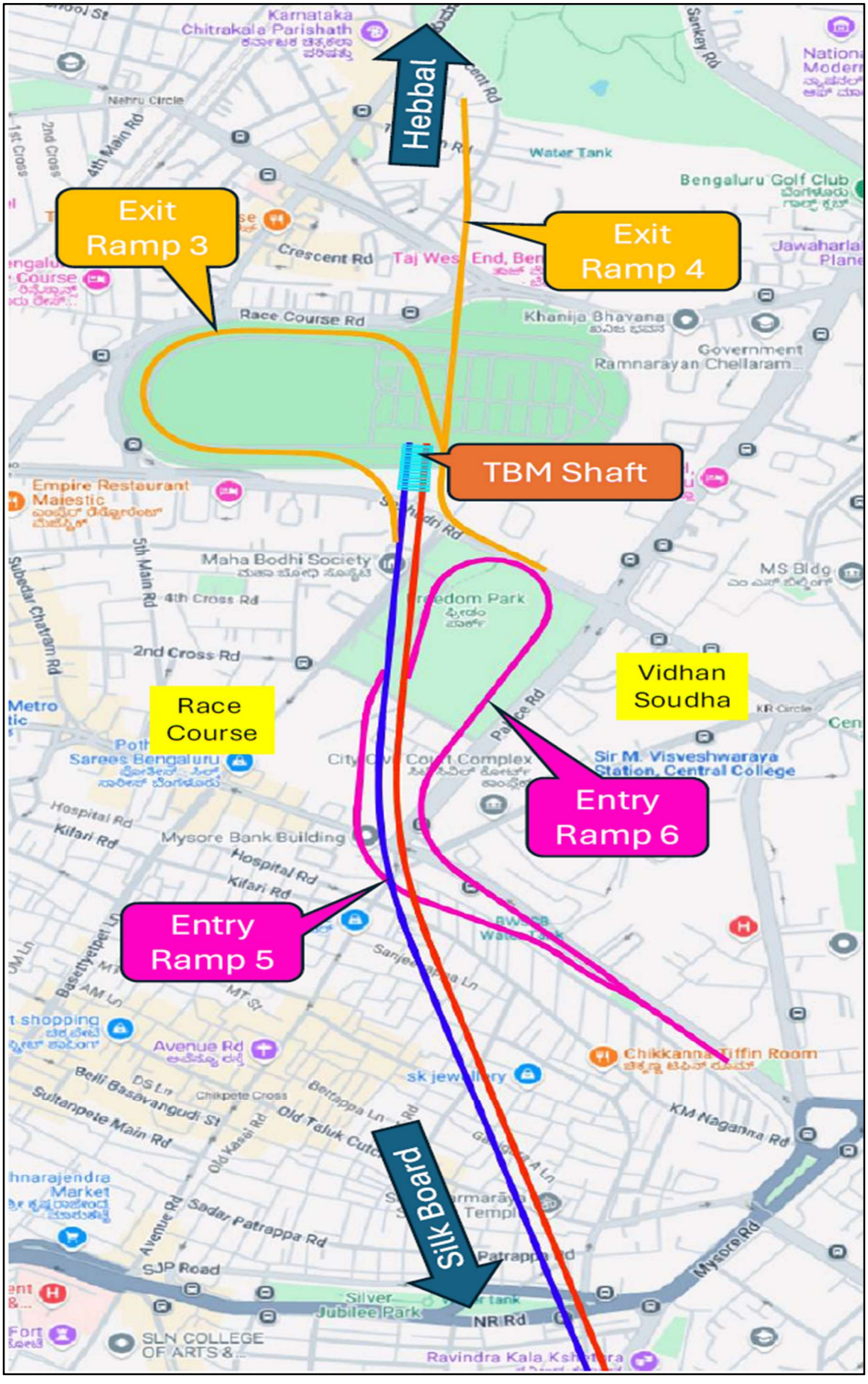
**Appendix-A-I**

## Index Map of Project Highway

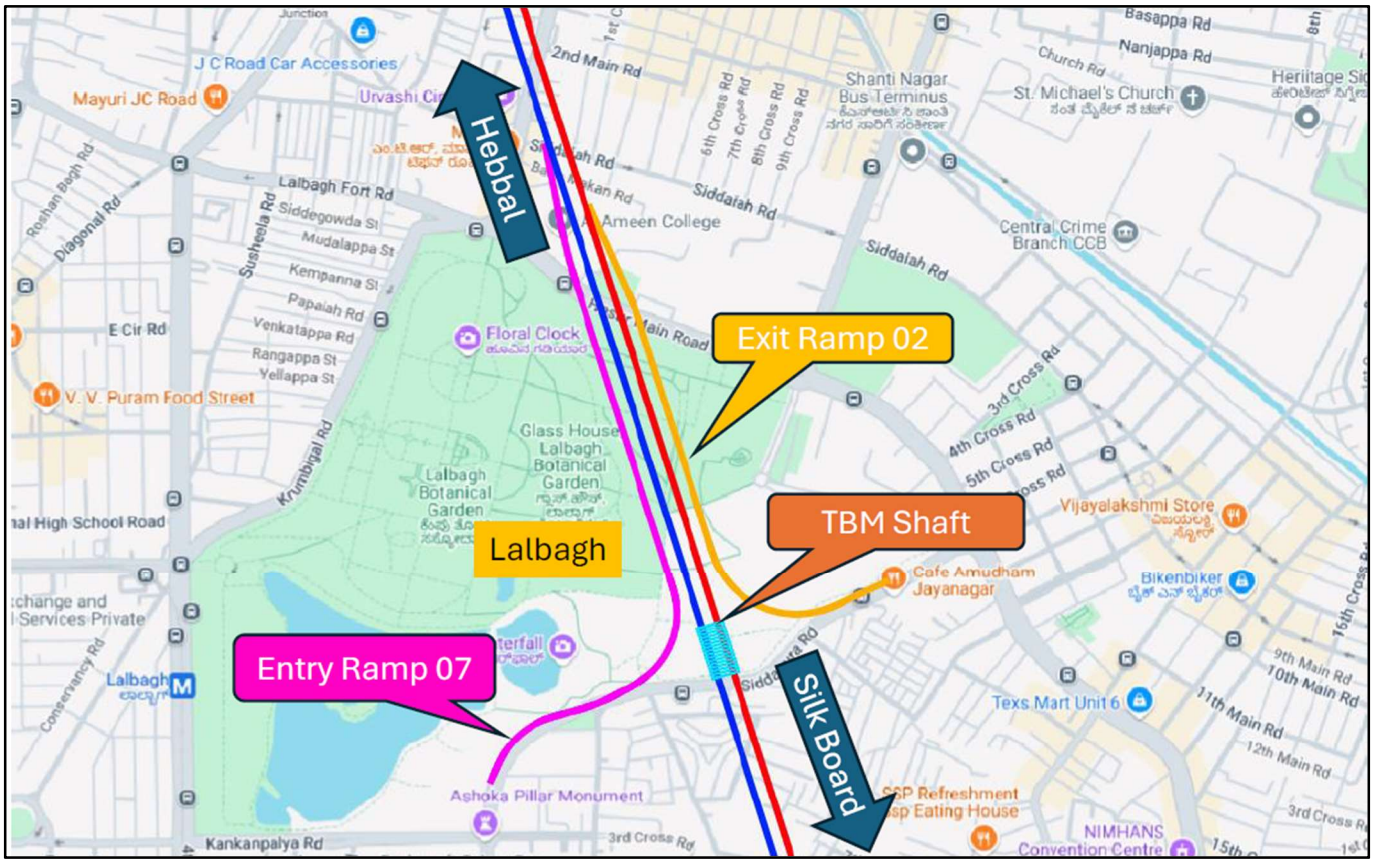


**Appendix-A-I**

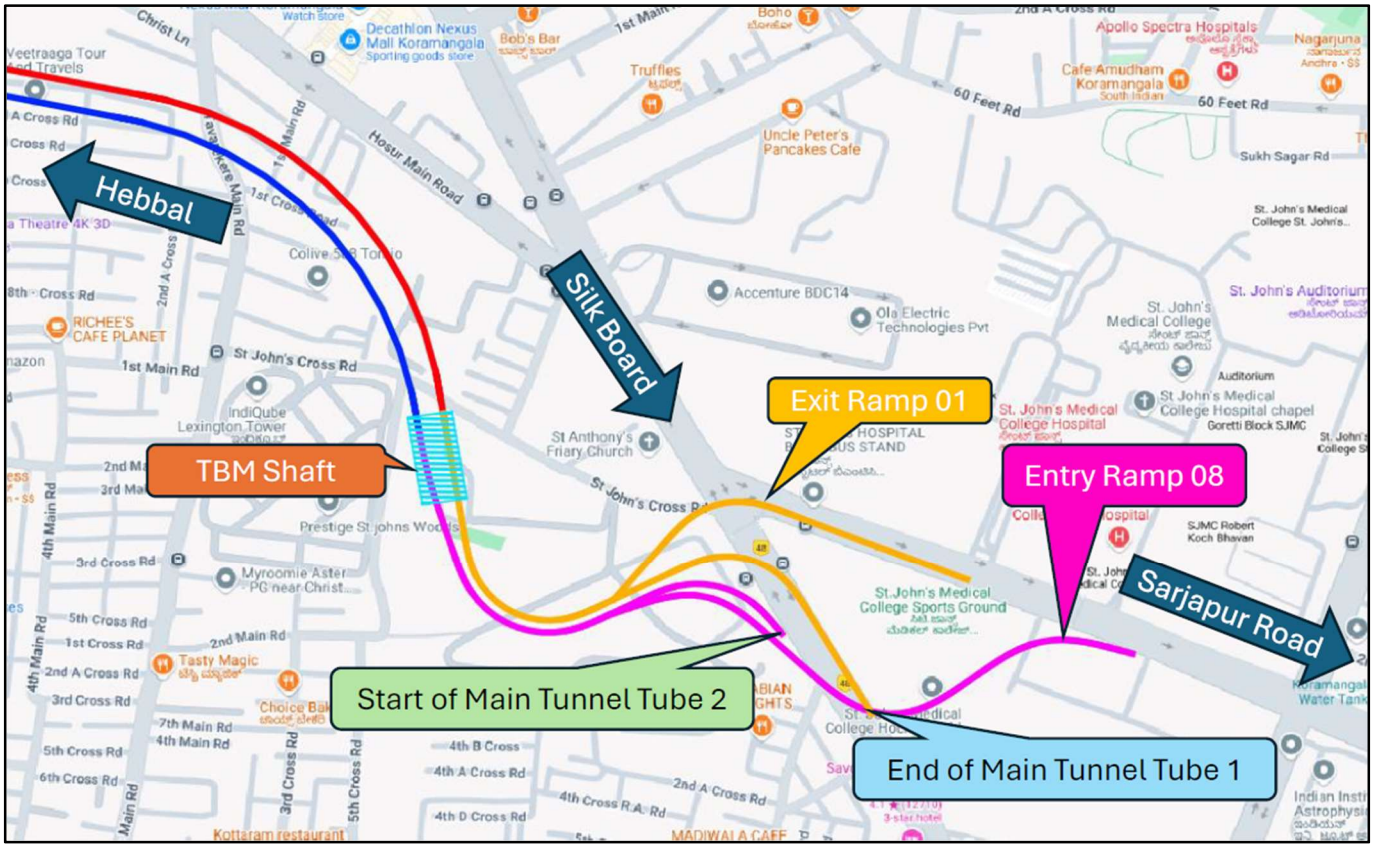
## Entry and Exit at Race Course



## Entry and Exit Ramps at LalBagh Botanical garden




## Entry and Exit Ramps at Silk Board Junction



## Appendix A-II

## Coordinate System - Universal Transverse Mercator (UTM)-WGS84 (Zone 43N)

## Package-2 (Design Chainage Km 8+748 to Km 16+745)

## Centerline Coordinates of Tube-I (LHS)

| SL No. | Chainage (m) | Easting-X | Northing-Y |
|---|---|---|---|
| 1 | 8751.5 | 780055.550 | 1436470.791 |
| 2 | 8761.5 | 780054.924 | 1436460.811 |
| 3 | 8771.5 | 780054.298 | 1436450.830 |
| 4 | 8781.5 | 780053.672 | 1436440.850 |
| 5 | 8791.5 | 780053.046 | 1436430.869 |
| 6 | 8801.5 | 780052.420 | 1436420.889 |
| 7 | 8811.5 | 780051.794 | 1436410.909 |
| 8 | 8821.5 | 780051.168 | 1436400.928 |
| 9 | 8831.5 | 780050.542 | 1436390.948 |
| 10 | 8841.5 | 780049.916 | 1436380.968 |
| 11 | 8851.5 | 780049.290 | 1436370.987 |
| 12 | 8861.5 | 780048.664 | 1436361.007 |
| 13 | 8871.5 | 780048.038 | 1436351.026 |
| 14 | 8881.5 | 780047.411 | 1436341.046 |
| 15 | 8891.5 | 780046.785 | 1436331.066 |
| 16 | 8901.5 | 780046.159 | 1436321.085 |
| 17 | 8911.5 | 780045.533 | 1436311.105 |
| 18 | 8921.5 | 780044.907 | 1436301.124 |
| 19 | 8931.5 | 780044.281 | 1436291.144 |
| 20 | 8941.5 | 780043.655 | 1436281.164 |
| 21 | 8951.5 | 780043.029 | 1436271.183 |
| 22 | 8961.5 | 780042.403 | 1436261.203 |
| 23 | 8971.5 | 780041.777 | 1436251.223 |
| 24 | 8981.5 | 780041.151 | 1436241.242 |
| 25 | 8991.5 | 780040.525 | 1436231.262 |
| 26 | 9001.5 | 780039.899 | 1436221.281 |
| 27 | 9011.5 | 780039.272 | 1436211.301 |
| 28 | 9021.5 | 780038.646 | 1436201.321 |
| 29 | 9031.5 | 780038.020 | 1436191.340 |
| 30 | 9041.5 | 780037.394 | 1436181.360 |
| 31 | 9051.5 | 780036.768 | 1436171.380 |
| 32 | 9061.5 | 780036.142 | 1436161.399 |
| 33 | 9071.5 | 780035.516 | 1436151.419 |
| 34 | 9081.5 | 780034.890 | 1436141.438 |
| 35 | 9091.5 | 780034.264 | 1436131.458 |
| 36 | 9101.5 | 780033.638 | 1436121.478 |
| 37 | 9111.5 | 780033.012 | 1436111.497 |
| 38 | 9121.5 | 780032.386 | 1436101.517 |
| 39 | 9131.5 | 780031.760 | 1436091.536 |
| 40 | 9141.5 | 780031.134 | 1436081.556 |
| 41 | 9151.5 | 780030.507 | 1436071.576 |
| 42 | 9161.5 | 780029.881 | 1436061.595 |
| 43 | 9171.5 | 780029.255 | 1436051.615 |
| 44 | 9181.5 | 780028.629 | 1436041.635 |
| 45 | 9191.5 | 780028.003 | 1436031.654 |
| 46 | 9201.5 | 780027.377 | 1436021.674 |
| 47 | 9211.5 | 780026.751 | 1436011.693 |

| SL No. | Chainage (m) | Easting-X | Northing-Y |
|---|---|---|---|
| 48 | 9221.5 | 780026.125 | 1436001.713 |
| 49 | 9231.5 | 780025.499 | 1435991.733 |
| 50 | 9241.5 | 780024.873 | 1435981.752 |
| 51 | 9251.5 | 780024.247 | 1435971.772 |
| 52 | 9261.5 | 780023.621 | 1435961.791 |
| 53 | 9271.5 | 780022.995 | 1435951.811 |
| 54 | 9281.5 | 780022.368 | 1435941.831 |
| 55 | 9291.5 | 780021.742 | 1435931.850 |
| 56 | 9301.5 | 780021.116 | 1435921.870 |
| 57 | 9311.5 | 780020.490 | 1435911.890 |
| 58 | 9321.5 | 780019.864 | 1435901.909 |
| 59 | 9331.5 | 780019.238 | 1435891.929 |
| 60 | 9341.5 | 780018.612 | 1435881.948 |
| 61 | 9351.5 | 780017.986 | 1435871.968 |
| 62 | 9361.5 | 780017.360 | 1435861.988 |
| 63 | 9371.5 | 780016.735 | 1435852.007 |
| 64 | 9381.5 | 780016.118 | 1435842.026 |
| 65 | 9391.5 | 780015.515 | 1435832.044 |
| 66 | 9401.5 | 780014.934 | 1435822.061 |
| 67 | 9411.5 | 780014.382 | 1435812.077 |
| 68 | 9421.5 | 780013.866 | 1435802.090 |
| 69 | 9431.5 | 780013.394 | 1435792.101 |
| 70 | 9441.5 | 780012.972 | 1435782.110 |
| 71 | 9451.5 | 780012.609 | 1435772.117 |
| 72 | 9461.5 | 780012.310 | 1435762.121 |
| 73 | 9471.5 | 780012.085 | 1435752.124 |
| 74 | 9481.5 | 780011.939 | 1435742.125 |
| 75 | 9491.5 | 780011.876 | 1435732.125 |
| 76 | 9501.5 | 780011.897 | 1435722.125 |
| 77 | 9511.5 | 780012.001 | 1435712.126 |
| 78 | 9521.5 | 780012.188 | 1435702.127 |
| 79 | 9531.5 | 780012.458 | 1435692.131 |
| 80 | 9541.5 | 780012.812 | 1435682.137 |
| 81 | 9551.5 | 780013.249 | 1435672.147 |
| 82 | 9561.5 | 780013.770 | 1435662.161 |
| 83 | 9571.5 | 780014.373 | 1435652.179 |
| 84 | 9581.5 | 780015.060 | 1435642.202 |
| 85 | 9591.5 | 780015.830 | 1435632.232 |
| 86 | 9601.5 | 780016.683 | 1435622.269 |
| 87 | 9611.5 | 780017.618 | 1435612.312 |
| 88 | 9621.5 | 780018.637 | 1435602.365 |
| 89 | 9631.5 | 780019.739 | 1435592.425 |
| 90 | 9641.5 | 780020.923 | 1435582.496 |
| 91 | 9651.5 | 780022.190 | 1435572.577 |
| 92 | 9661.5 | 780023.540 | 1435562.668 |
| 93 | 9671.5 | 780024.972 | 1435552.771 |
| 94 | 9681.5 | 780026.487 | 1435542.887 |
| 95 | 9691.5 | 780028.084 | 1435533.015 |
| 96 | 9701.5 | 780029.763 | 1435523.157 |
| 97 | 9711.5 | 780031.525 | 1435513.313 |
| 98 | 9721.5 | 780033.368 | 1435503.485 |
| 99 | 9731.5 | 780035.293 | 1435493.672 |
| 100 | 9741.5 | 780037.300 | 1435483.875 |

| SL No. | Chainage (m) | Easting-X | Northing-Y |
|---|---|---|---|
| 101 | 9751.5 | 780039.388 | 1435474.096 |
| 102 | 9761.5 | 780041.558 | 1435464.334 |
| 103 | 9771.5 | 780043.809 | 1435454.591 |
| 104 | 9781.5 | 780046.142 | 1435444.867 |
| 105 | 9791.5 | 780048.555 | 1435435.162 |
| 106 | 9801.5 | 780051.049 | 1435425.478 |
| 107 | 9811.5 | 780053.623 | 1435415.815 |
| 108 | 9821.5 | 780056.277 | 1435406.174 |
| 109 | 9831.5 | 780059.002 | 1435396.552 |
| 110 | 9841.5 | 780061.794 | 1435386.950 |
| 111 | 9851.5 | 780064.643 | 1435377.365 |
| 112 | 9861.5 | 780067.544 | 1435367.794 |
| 113 | 9871.5 | 780070.489 | 1435358.238 |
| 114 | 9881.5 | 780073.471 | 1435348.693 |
| 115 | 9891.5 | 780076.483 | 1435339.157 |
| 116 | 9901.5 | 780079.519 | 1435329.629 |
| 117 | 9911.5 | 780082.571 | 1435320.107 |
| 118 | 9921.5 | 780085.633 | 1435310.587 |
| 119 | 9931.5 | 780088.698 | 1435301.068 |
| 120 | 9941.5 | 780091.763 | 1435291.549 |
| 121 | 9951.5 | 780094.827 | 1435282.030 |
| 122 | 9961.5 | 780097.892 | 1435272.512 |
| 123 | 9971.5 | 780100.957 | 1435262.993 |
| 124 | 9981.5 | 780104.021 | 1435253.474 |
| 125 | 9991.5 | 780107.086 | 1435243.955 |
| 126 | 10001.5 | 780110.151 | 1435234.437 |
| 127 | 10011.5 | 780113.216 | 1435224.918 |
| 128 | 10021.5 | 780116.280 | 1435215.399 |
| 129 | 10031.5 | 780119.345 | 1435205.880 |
| 130 | 10041.5 | 780122.410 | 1435196.361 |
| 131 | 10051.5 | 780125.475 | 1435186.843 |
| 132 | 10061.5 | 780128.539 | 1435177.324 |
| 133 | 10071.5 | 780131.604 | 1435167.805 |
| 134 | 10081.5 | 780134.669 | 1435158.286 |
| 135 | 10091.5 | 780137.734 | 1435148.767 |
| 136 | 10101.5 | 780140.798 | 1435139.249 |
| 137 | 10111.5 | 780143.863 | 1435129.730 |
| 138 | 10121.5 | 780146.928 | 1435120.211 |
| 139 | 10131.5 | 780149.993 | 1435110.692 |
| 140 | 10141.5 | 780153.057 | 1435101.173 |
| 141 | 10151.5 | 780156.122 | 1435091.655 |
| 142 | 10161.5 | 780159.187 | 1435082.136 |
| 143 | 10171.5 | 780162.252 | 1435072.617 |
| 144 | 10181.5 | 780165.316 | 1435063.098 |
| 145 | 10191.5 | 780168.381 | 1435053.580 |
| 146 | 10201.5 | 780171.446 | 1435044.061 |
| 147 | 10211.5 | 780174.511 | 1435034.542 |
| 148 | 10221.5 | 780177.575 | 1435025.023 |
| 149 | 10231.5 | 780180.640 | 1435015.504 |
| 150 | 10241.5 | 780183.705 | 1435005.986 |
| 151 | 10251.5 | 780186.769 | 1434996.467 |
| 152 | 10261.5 | 780189.834 | 1434986.948 |
| 153 | 10271.5 | 780192.899 | 1434977.429 |

| SL No. | Chainage (m) | Easting-X | Northing-Y |
|---|---|---|---|
| 154 | 10281.5 | 780195.964 | 1434967.910 |
| 155 | 10291.5 | 780199.028 | 1434958.392 |
| 156 | 10301.5 | 780202.093 | 1434948.873 |
| 157 | 10311.5 | 780205.158 | 1434939.354 |
| 158 | 10321.5 | 780208.223 | 1434929.835 |
| 159 | 10331.5 | 780211.287 | 1434920.316 |
| 160 | 10341.5 | 780214.352 | 1434910.798 |
| 161 | 10351.5 | 780217.417 | 1434901.279 |
| 162 | 10361.5 | 780220.482 | 1434891.760 |
| 163 | 10371.5 | 780223.546 | 1434882.241 |
| 164 | 10381.5 | 780226.611 | 1434872.723 |
| 165 | 10391.5 | 780229.676 | 1434863.204 |
| 166 | 10401.5 | 780232.741 | 1434853.685 |
| 167 | 10411.5 | 780235.805 | 1434844.166 |
| 168 | 10421.5 | 780238.870 | 1434834.647 |
| 169 | 10431.5 | 780241.935 | 1434825.129 |
| 170 | 10441.5 | 780245.000 | 1434815.610 |
| 171 | 10451.5 | 780248.064 | 1434806.091 |
| 172 | 10461.5 | 780251.129 | 1434796.572 |
| 173 | 10471.5 | 780254.194 | 1434787.053 |
| 174 | 10481.5 | 780257.259 | 1434777.535 |
| 175 | 10491.5 | 780260.323 | 1434768.016 |
| 176 | 10501.5 | 780263.388 | 1434758.497 |
| 177 | 10511.5 | 780266.453 | 1434748.978 |
| 178 | 10521.5 | 780269.517 | 1434739.459 |
| 179 | 10531.5 | 780272.582 | 1434729.941 |
| 180 | 10541.5 | 780275.647 | 1434720.422 |
| 181 | 10551.5 | 780278.712 | 1434710.903 |
| 182 | 10561.5 | 780281.776 | 1434701.384 |
| 183 | 10571.5 | 780284.841 | 1434691.866 |
| 184 | 10581.5 | 780287.906 | 1434682.347 |
| 185 | 10591.5 | 780290.971 | 1434672.828 |
| 186 | 10601.5 | 780294.035 | 1434663.309 |
| 187 | 10611.5 | 780297.100 | 1434653.790 |
| 188 | 10621.5 | 780300.165 | 1434644.272 |
| 189 | 10631.5 | 780303.230 | 1434634.753 |
| 190 | 10641.5 | 780306.294 | 1434625.234 |
| 191 | 10651.5 | 780309.359 | 1434615.715 |
| 192 | 10661.5 | 780312.424 | 1434606.196 |
| 193 | 10671.5 | 780315.489 | 1434596.678 |
| 194 | 10681.5 | 780318.553 | 1434587.159 |
| 195 | 10691.5 | 780321.618 | 1434577.640 |
| 196 | 10701.5 | 780324.683 | 1434568.121 |
| 197 | 10711.5 | 780327.748 | 1434558.602 |
| 198 | 10721.5 | 780330.812 | 1434549.084 |
| 199 | 10731.5 | 780333.877 | 1434539.565 |
| 200 | 10741.5 | 780336.942 | 1434530.046 |
| 201 | 10751.5 | 780340.007 | 1434520.527 |
| 202 | 10761.5 | 780343.071 | 1434511.008 |
| 203 | 10771.5 | 780346.136 | 1434501.490 |
| 204 | 10781.5 | 780349.201 | 1434491.971 |
| 205 | 10791.5 | 780352.265 | 1434482.452 |
| 206 | 10801.5 | 780355.330 | 1434472.933 |

| SL No. | Chainage (m) | Easting-X | Northing-Y |
|---|---|---|---|
| 207 | 10811.5 | 780358.395 | 1434463.415 |
| 208 | 10821.5 | 780361.460 | 1434453.896 |
| 209 | 10831.5 | 780364.524 | 1434444.377 |
| 210 | 10841.5 | 780367.589 | 1434434.858 |
| 211 | 10851.5 | 780370.654 | 1434425.339 |
| 212 | 10861.5 | 780373.719 | 1434415.821 |
| 213 | 10871.5 | 780376.783 | 1434406.302 |
| 214 | 10881.5 | 780379.848 | 1434396.783 |
| 215 | 10891.5 | 780382.913 | 1434387.264 |
| 216 | 10901.5 | 780385.978 | 1434377.745 |
| 217 | 10911.5 | 780389.042 | 1434368.227 |
| 218 | 10921.5 | 780392.107 | 1434358.708 |
| 219 | 10931.5 | 780395.172 | 1434349.189 |
| 220 | 10941.5 | 780398.237 | 1434339.670 |
| 221 | 10951.5 | 780401.301 | 1434330.151 |
| 222 | 10961.5 | 780404.366 | 1434320.633 |
| 223 | 10971.5 | 780407.431 | 1434311.114 |
| 224 | 10981.5 | 780410.496 | 1434301.595 |
| 225 | 10991.5 | 780413.560 | 1434292.076 |
| 226 | 11001.5 | 780416.625 | 1434282.558 |
| 227 | 11011.5 | 780419.690 | 1434273.039 |
| 228 | 11021.5 | 780422.755 | 1434263.520 |
| 229 | 11031.5 | 780425.819 | 1434254.001 |
| 230 | 11041.5 | 780428.884 | 1434244.482 |
| 231 | 11051.5 | 780431.949 | 1434234.964 |
| 232 | 11061.5 | 780435.013 | 1434225.445 |
| 233 | 11071.5 | 780438.078 | 1434215.926 |
| 234 | 11081.5 | 780441.143 | 1434206.407 |
| 235 | 11091.5 | 780444.208 | 1434196.888 |
| 236 | 11101.5 | 780447.272 | 1434187.370 |
| 237 | 11111.5 | 780450.337 | 1434177.851 |
| 238 | 11121.5 | 780453.402 | 1434168.332 |
| 239 | 11131.5 | 780456.467 | 1434158.813 |
| 240 | 11141.5 | 780459.531 | 1434149.294 |
| 241 | 11151.5 | 780462.596 | 1434139.776 |
| 242 | 11161.5 | 780465.661 | 1434130.257 |
| 243 | 11171.5 | 780468.726 | 1434120.738 |
| 244 | 11181.5 | 780471.790 | 1434111.219 |
| 245 | 11191.5 | 780474.855 | 1434101.701 |
| 246 | 11201.5 | 780477.920 | 1434092.182 |
| 247 | 11211.5 | 780480.985 | 1434082.663 |
| 248 | 11221.5 | 780484.049 | 1434073.144 |
| 249 | 11231.5 | 780487.114 | 1434063.625 |
| 250 | 11241.5 | 780490.179 | 1434054.107 |
| 251 | 11251.5 | 780493.244 | 1434044.588 |
| 252 | 11261.5 | 780496.308 | 1434035.069 |
| 253 | 11271.5 | 780499.373 | 1434025.550 |
| 254 | 11281.5 | 780502.438 | 1434016.031 |
| 255 | 11291.5 | 780505.503 | 1434006.513 |
| 256 | 11301.5 | 780508.567 | 1433996.994 |
| 257 | 11311.5 | 780511.632 | 1433987.475 |
| 258 | 11321.5 | 780514.697 | 1433977.956 |
| 259 | 11331.5 | 780517.761 | 1433968.437 |

| SL No. | Chainage (m) | Easting-X | Northing-Y |
|---|---|---|---|
| 260 | 11341.5 | 780520.826 | 1433958.919 |
| 261 | 11351.5 | 780523.891 | 1433949.400 |
| 262 | 11361.5 | 780526.956 | 1433939.881 |
| 263 | 11371.5 | 780530.020 | 1433930.362 |
| 264 | 11381.5 | 780533.085 | 1433920.844 |
| 265 | 11391.5 | 780536.150 | 1433911.325 |
| 266 | 11401.5 | 780539.215 | 1433901.806 |
| 267 | 11411.5 | 780542.279 | 1433892.287 |
| 268 | 11421.5 | 780545.344 | 1433882.768 |
| 269 | 11431.5 | 780548.409 | 1433873.250 |
| 270 | 11441.5 | 780551.474 | 1433863.731 |
| 271 | 11451.5 | 780554.538 | 1433854.212 |
| 272 | 11461.5 | 780557.603 | 1433844.693 |
| 273 | 11471.5 | 780560.668 | 1433835.174 |
| 274 | 11481.5 | 780563.733 | 1433825.656 |
| 275 | 11491.5 | 780566.797 | 1433816.137 |
| 276 | 11501.5 | 780569.862 | 1433806.618 |
| 277 | 11511.5 | 780572.927 | 1433797.099 |
| 278 | 11521.5 | 780575.992 | 1433787.580 |
| 279 | 11531.5 | 780579.056 | 1433778.062 |
| 280 | 11541.5 | 780582.121 | 1433768.543 |
| 281 | 11551.5 | 780585.186 | 1433759.024 |
| 282 | 11561.5 | 780588.251 | 1433749.505 |
| 283 | 11571.5 | 780591.315 | 1433739.986 |
| 284 | 11581.5 | 780594.380 | 1433730.468 |
| 285 | 11591.5 | 780597.445 | 1433720.949 |
| 286 | 11601.5 | 780600.509 | 1433711.430 |
| 287 | 11611.5 | 780603.574 | 1433701.911 |
| 288 | 11621.5 | 780606.639 | 1433692.393 |
| 289 | 11631.5 | 780609.704 | 1433682.874 |
| 290 | 11641.5 | 780612.768 | 1433673.355 |
| 291 | 11651.5 | 780615.833 | 1433663.836 |
| 292 | 11661.5 | 780618.898 | 1433654.317 |
| 293 | 11671.5 | 780621.963 | 1433644.799 |
| 294 | 11681.5 | 780625.027 | 1433635.280 |
| 295 | 11691.5 | 780628.092 | 1433625.761 |
| 296 | 11701.5 | 780631.157 | 1433616.242 |
| 297 | 11711.5 | 780634.222 | 1433606.723 |
| 298 | 11721.5 | 780637.286 | 1433597.205 |
| 299 | 11731.5 | 780640.351 | 1433587.686 |
| 300 | 11741.5 | 780643.416 | 1433578.167 |
| 301 | 11751.5 | 780646.481 | 1433568.648 |
| 302 | 11761.5 | 780649.545 | 1433559.129 |
| 303 | 11771.5 | 780652.610 | 1433549.611 |
| 304 | 11781.5 | 780655.675 | 1433540.092 |
| 305 | 11791.5 | 780658.740 | 1433530.573 |
| 306 | 11801.5 | 780661.804 | 1433521.054 |
| 307 | 11811.5 | 780664.869 | 1433511.536 |
| 308 | 11821.5 | 780667.934 | 1433502.017 |
| 309 | 11831.5 | 780670.999 | 1433492.498 |
| 310 | 11841.5 | 780674.063 | 1433482.979 |
| 311 | 11851.5 | 780677.128 | 1433473.460 |
| 312 | 11861.5 | 780680.193 | 1433463.942 |

| SL No. | Chainage (m) | Easting-X | Northing-Y |
|---|---|---|---|
| 313 | 11871.5 | 780683.257 | 1433454.423 |
| 314 | 11881.5 | 780686.322 | 1433444.904 |
| 315 | 11891.5 | 780689.387 | 1433435.385 |
| 316 | 11901.5 | 780692.452 | 1433425.866 |
| 317 | 11911.5 | 780695.516 | 1433416.348 |
| 318 | 11921.5 | 780698.581 | 1433406.829 |
| 319 | 11931.5 | 780701.646 | 1433397.310 |
| 320 | 11941.5 | 780704.711 | 1433387.791 |
| 321 | 11951.5 | 780707.775 | 1433378.272 |
| 322 | 11961.5 | 780710.840 | 1433368.754 |
| 323 | 11971.5 | 780713.905 | 1433359.235 |
| 324 | 11981.5 | 780716.970 | 1433349.716 |
| 325 | 11991.5 | 780720.034 | 1433340.197 |
| 326 | 12001.5 | 780723.099 | 1433330.679 |
| 327 | 12011.5 | 780726.164 | 1433321.160 |
| 328 | 12021.5 | 780729.229 | 1433311.641 |
| 329 | 12031.5 | 780732.293 | 1433302.122 |
| 330 | 12041.5 | 780735.358 | 1433292.603 |
| 331 | 12051.5 | 780738.423 | 1433283.085 |
| 332 | 12061.5 | 780741.488 | 1433273.566 |
| 333 | 12071.5 | 780744.552 | 1433264.047 |
| 334 | 12081.5 | 780747.617 | 1433254.528 |
| 335 | 12091.5 | 780750.682 | 1433245.009 |
| 336 | 12101.5 | 780753.747 | 1433235.491 |
| 337 | 12111.5 | 780756.811 | 1433225.972 |
| 338 | 12121.5 | 780759.876 | 1433216.453 |
| 339 | 12131.5 | 780762.941 | 1433206.934 |
| 340 | 12141.5 | 780766.005 | 1433197.415 |
| 341 | 12151.5 | 780769.070 | 1433187.897 |
| 342 | 12161.5 | 780772.135 | 1433178.378 |
| 343 | 12171.5 | 780775.200 | 1433168.859 |
| 344 | 12181.5 | 780778.264 | 1433159.340 |
| 345 | 12191.5 | 780781.329 | 1433149.822 |
| 346 | 12201.5 | 780784.394 | 1433140.303 |
| 347 | 12211.5 | 780787.459 | 1433130.784 |
| 348 | 12221.5 | 780790.523 | 1433121.265 |
| 349 | 12231.5 | 780793.588 | 1433111.746 |
| 350 | 12241.5 | 780796.653 | 1433102.228 |
| 351 | 12251.5 | 780799.718 | 1433092.709 |
| 352 | 12261.5 | 780802.782 | 1433083.190 |
| 353 | 12271.5 | 780805.847 | 1433073.671 |
| 354 | 12281.5 | 780808.912 | 1433064.152 |
| 355 | 12291.5 | 780811.977 | 1433054.634 |
| 356 | 12301.5 | 780815.041 | 1433045.115 |
| 357 | 12311.5 | 780818.106 | 1433035.596 |
| 358 | 12321.5 | 780821.171 | 1433026.077 |
| 359 | 12331.5 | 780824.236 | 1433016.558 |
| 360 | 12341.5 | 780827.300 | 1433007.040 |
| 361 | 12351.5 | 780830.365 | 1432997.521 |
| 362 | 12361.5 | 780833.430 | 1432988.002 |
| 363 | 12371.5 | 780836.495 | 1432978.483 |
| 364 | 12381.5 | 780839.559 | 1432968.965 |
| 365 | 12391.5 | 780842.624 | 1432959.446 |

| SL No. | Chainage (m) | Easting-X | Northing-Y |
|---|---|---|---|
| 366 | 12401.5 | 780845.689 | 1432949.927 |
| 367 | 12411.5 | 780848.753 | 1432940.408 |
| 368 | 12421.5 | 780851.818 | 1432930.889 |
| 369 | 12431.5 | 780854.883 | 1432921.371 |
| 370 | 12441.5 | 780857.948 | 1432911.852 |
| 371 | 12451.5 | 780861.012 | 1432902.333 |
| 372 | 12461.5 | 780864.077 | 1432892.814 |
| 373 | 12471.5 | 780867.142 | 1432883.295 |
| 374 | 12481.5 | 780870.207 | 1432873.777 |
| 375 | 12491.5 | 780873.271 | 1432864.258 |
| 376 | 12501.5 | 780876.336 | 1432854.739 |
| 377 | 12511.5 | 780879.401 | 1432845.220 |
| 378 | 12521.5 | 780882.466 | 1432835.701 |
| 379 | 12531.5 | 780885.530 | 1432826.183 |
| 380 | 12541.5 | 780888.595 | 1432816.664 |
| 381 | 12551.5 | 780891.660 | 1432807.145 |
| 382 | 12561.5 | 780894.725 | 1432797.626 |
| 383 | 12571.5 | 780897.789 | 1432788.107 |
| 384 | 12581.5 | 780900.854 | 1432778.589 |
| 385 | 12591.5 | 780903.919 | 1432769.070 |
| 386 | 12601.5 | 780906.984 | 1432759.551 |
| 387 | 12611.5 | 780910.048 | 1432750.032 |
| 388 | 12621.5 | 780913.113 | 1432740.514 |
| 389 | 12631.5 | 780916.178 | 1432730.995 |
| 390 | 12641.5 | 780919.243 | 1432721.476 |
| 391 | 12651.5 | 780922.307 | 1432711.957 |
| 392 | 12661.5 | 780925.372 | 1432702.438 |
| 393 | 12671.5 | 780928.437 | 1432692.920 |
| 394 | 12681.5 | 780931.501 | 1432683.401 |
| 395 | 12691.5 | 780934.566 | 1432673.882 |
| 396 | 12701.5 | 780937.631 | 1432664.363 |
| 397 | 12711.5 | 780940.696 | 1432654.844 |
| 398 | 12721.5 | 780943.760 | 1432645.326 |
| 399 | 12731.5 | 780946.825 | 1432635.807 |
| 400 | 12741.5 | 780949.890 | 1432626.288 |
| 401 | 12751.5 | 780952.955 | 1432616.769 |
| 402 | 12761.5 | 780956.019 | 1432607.250 |
| 403 | 12771.5 | 780959.084 | 1432597.732 |
| 404 | 12781.5 | 780962.149 | 1432588.213 |
| 405 | 12791.5 | 780965.214 | 1432578.694 |
| 406 | 12801.5 | 780968.278 | 1432569.175 |
| 407 | 12811.5 | 780971.343 | 1432559.657 |
| 408 | 12821.5 | 780974.408 | 1432550.138 |
| 409 | 12831.5 | 780977.473 | 1432540.619 |
| 410 | 12841.5 | 780980.537 | 1432531.100 |
| 411 | 12851.5 | 780983.602 | 1432521.581 |
| 412 | 12861.5 | 780986.667 | 1432512.063 |
| 413 | 12871.5 | 780989.732 | 1432502.544 |
| 414 | 12881.5 | 780992.796 | 1432493.025 |
| 415 | 12891.5 | 780995.861 | 1432483.506 |
| 416 | 12901.5 | 780998.926 | 1432473.987 |
| 417 | 12911.5 | 781001.991 | 1432464.469 |
| 418 | 12921.5 | 781005.055 | 1432454.950 |

| SL No. | Chainage (m) | Easting-X | Northing-Y |
|---|---|---|---|
| 419 | 12931.5 | 781008.120 | 1432445.431 |
| 420 | 12941.5 | 781011.185 | 1432435.912 |
| 421 | 12951.5 | 781014.250 | 1432426.393 |
| 422 | 12961.5 | 781017.314 | 1432416.875 |
| 423 | 12971.5 | 781020.379 | 1432407.356 |
| 424 | 12981.5 | 781023.444 | 1432397.837 |
| 425 | 12991.5 | 781026.508 | 1432388.318 |
| 426 | 13001.5 | 781029.573 | 1432378.800 |
| 427 | 13011.5 | 781032.638 | 1432369.281 |
| 428 | 13021.5 | 781035.703 | 1432359.762 |
| 429 | 13031.5 | 781038.767 | 1432350.243 |
| 430 | 13041.5 | 781041.832 | 1432340.724 |
| 431 | 13051.5 | 781044.897 | 1432331.206 |
| 432 | 13061.5 | 781047.962 | 1432321.687 |
| 433 | 13071.5 | 781051.026 | 1432312.168 |
| 434 | 13081.5 | 781054.091 | 1432302.649 |
| 435 | 13091.5 | 781057.156 | 1432293.130 |
| 436 | 13101.5 | 781060.221 | 1432283.612 |
| 437 | 13111.5 | 781063.286 | 1432274.093 |
| 438 | 13121.5 | 781066.364 | 1432264.579 |
| 439 | 13131.5 | 781069.476 | 1432255.075 |
| 440 | 13141.5 | 781072.641 | 1432245.589 |
| 441 | 13151.5 | 781075.881 | 1432236.129 |
| 442 | 13161.5 | 781079.216 | 1432226.701 |
| 443 | 13171.5 | 781082.665 | 1432217.315 |
| 444 | 13181.5 | 781086.248 | 1432207.979 |
| 445 | 13191.5 | 781089.986 | 1432198.704 |
| 446 | 13201.5 | 781093.896 | 1432189.500 |
| 447 | 13211.5 | 781097.998 | 1432180.380 |
| 448 | 13221.5 | 781102.309 | 1432171.358 |
| 449 | 13231.5 | 781106.842 | 1432162.444 |
| 450 | 13241.5 | 781111.596 | 1432153.647 |
| 451 | 13251.5 | 781116.569 | 1432144.971 |
| 452 | 13261.5 | 781121.757 | 1432136.423 |
| 453 | 13271.5 | 781127.157 | 1432128.007 |
| 454 | 13281.5 | 781132.766 | 1432119.728 |
| 455 | 13291.5 | 781138.580 | 1432111.592 |
| 456 | 13301.5 | 781144.595 | 1432103.604 |
| 457 | 13311.5 | 781150.808 | 1432095.769 |
| 458 | 13321.5 | 781157.216 | 1432088.091 |
| 459 | 13331.5 | 781163.813 | 1432080.577 |
| 460 | 13341.5 | 781170.596 | 1432073.229 |
| 461 | 13351.5 | 781177.560 | 1432066.053 |
| 462 | 13361.5 | 781184.702 | 1432059.054 |
| 463 | 13371.5 | 781192.016 | 1432052.235 |
| 464 | 13381.5 | 781199.499 | 1432045.602 |
| 465 | 13391.5 | 781207.145 | 1432039.157 |
| 466 | 13401.5 | 781214.950 | 1432032.906 |
| 467 | 13411.5 | 781222.908 | 1432026.851 |
| 468 | 13421.5 | 781231.007 | 1432020.986 |
| 469 | 13431.5 | 781239.231 | 1432015.297 |
| 470 | 13441.5 | 781247.563 | 1432009.768 |
| 471 | 13451.5 | 781255.990 | 1432004.383 |

| SL No. | Chainage (m) | Easting-X | Northing-Y |
|---|---|---|---|
| 472 | 13461.5 | 781264.496 | 1431999.125 |
| 473 | 13471.5 | 781273.068 | 1431993.976 |
| 474 | 13481.5 | 781281.696 | 1431988.920 |
| 475 | 13491.5 | 781290.365 | 1431983.936 |
| 476 | 13501.5 | 781299.066 | 1431979.008 |
| 477 | 13511.5 | 781307.788 | 1431974.115 |
| 478 | 13521.5 | 781316.519 | 1431969.240 |
| 479 | 13531.5 | 781325.251 | 1431964.367 |
| 480 | 13541.5 | 781333.984 | 1431959.494 |
| 481 | 13551.5 | 781342.716 | 1431954.621 |
| 482 | 13561.5 | 781351.448 | 1431949.748 |
| 483 | 13571.5 | 781360.181 | 1431944.875 |
| 484 | 13581.5 | 781368.913 | 1431940.002 |
| 485 | 13591.5 | 781377.645 | 1431935.129 |
| 486 | 13601.5 | 781386.377 | 1431930.255 |
| 487 | 13611.5 | 781395.110 | 1431925.382 |
| 488 | 13621.5 | 781403.842 | 1431920.509 |
| 489 | 13631.5 | 781412.574 | 1431915.636 |
| 490 | 13641.5 | 781421.307 | 1431910.763 |
| 491 | 13651.5 | 781430.039 | 1431905.890 |
| 492 | 13661.5 | 781438.771 | 1431901.017 |
| 493 | 13671.5 | 781447.504 | 1431896.144 |
| 494 | 13681.5 | 781456.236 | 1431891.271 |
| 495 | 13691.5 | 781464.968 | 1431886.398 |
| 496 | 13701.5 | 781473.701 | 1431881.525 |
| 497 | 13711.5 | 781482.433 | 1431876.652 |
| 498 | 13721.5 | 781491.165 | 1431871.779 |
| 499 | 13731.5 | 781499.898 | 1431866.906 |
| 500 | 13741.5 | 781508.630 | 1431862.033 |
| 501 | 13751.5 | 781517.362 | 1431857.160 |
| 502 | 13761.5 | 781526.095 | 1431852.287 |
| 503 | 13771.5 | 781534.827 | 1431847.414 |
| 504 | 13781.5 | 781543.559 | 1431842.541 |
| 505 | 13791.5 | 781552.292 | 1431837.668 |
| 506 | 13801.5 | 781561.024 | 1431832.795 |
| 507 | 13811.5 | 781569.756 | 1431827.921 |
| 508 | 13821.5 | 781578.489 | 1431823.048 |
| 509 | 13831.5 | 781587.221 | 1431818.175 |
| 510 | 13841.5 | 781595.953 | 1431813.302 |
| 511 | 13851.5 | 781604.685 | 1431808.429 |
| 512 | 13861.5 | 781613.418 | 1431803.556 |
| 513 | 13871.5 | 781622.150 | 1431798.683 |
| 514 | 13881.5 | 781630.882 | 1431793.810 |
| 515 | 13891.5 | 781639.615 | 1431788.937 |
| 516 | 13901.5 | 781648.347 | 1431784.064 |
| 517 | 13911.5 | 781657.079 | 1431779.191 |
| 518 | 13921.5 | 781665.812 | 1431774.318 |
| 519 | 13931.5 | 781674.544 | 1431769.445 |
| 520 | 13941.5 | 781683.276 | 1431764.572 |
| 521 | 13951.5 | 781692.009 | 1431759.699 |
| 522 | 13961.5 | 781700.741 | 1431754.826 |
| 523 | 13971.5 | 781709.473 | 1431749.953 |
| 524 | 13981.5 | 781718.206 | 1431745.080 |

| SL No. | Chainage (m) | Easting-X | Northing-Y |
|---|---|---|---|
| 525 | 13991.5 | 781726.938 | 1431740.207 |
| 526 | 14001.5 | 781735.670 | 1431735.334 |
| 527 | 14011.5 | 781744.403 | 1431730.461 |
| 528 | 14021.5 | 781753.135 | 1431725.588 |
| 529 | 14031.5 | 781761.867 | 1431720.714 |
| 530 | 14041.5 | 781770.600 | 1431715.841 |
| 531 | 14051.5 | 781779.332 | 1431710.968 |
| 532 | 14061.5 | 781788.064 | 1431706.095 |
| 533 | 14071.5 | 781796.797 | 1431701.222 |
| 534 | 14081.5 | 781805.529 | 1431696.349 |
| 535 | 14091.5 | 781814.261 | 1431691.476 |
| 536 | 14101.5 | 781822.993 | 1431686.603 |
| 537 | 14111.5 | 781831.726 | 1431681.730 |
| 538 | 14121.5 | 781840.458 | 1431676.857 |
| 539 | 14131.5 | 781849.190 | 1431671.984 |
| 540 | 14141.5 | 781857.923 | 1431667.111 |
| 541 | 14151.5 | 781866.655 | 1431662.238 |
| 542 | 14161.5 | 781875.387 | 1431657.365 |
| 543 | 14171.5 | 781884.120 | 1431652.492 |
| 544 | 14181.5 | 781892.852 | 1431647.619 |
| 545 | 14191.5 | 781901.584 | 1431642.746 |
| 546 | 14201.5 | 781910.317 | 1431637.873 |
| 547 | 14211.5 | 781919.049 | 1431633.000 |
| 548 | 14221.5 | 781927.781 | 1431628.127 |
| 549 | 14231.5 | 781936.514 | 1431623.254 |
| 550 | 14241.5 | 781945.246 | 1431618.380 |
| 551 | 14251.5 | 781953.978 | 1431613.507 |
| 552 | 14261.5 | 781962.711 | 1431608.634 |
| 553 | 14271.5 | 781971.443 | 1431603.761 |
| 554 | 14281.5 | 781980.175 | 1431598.888 |
| 555 | 14291.5 | 781988.908 | 1431594.015 |
| 556 | 14301.5 | 781997.640 | 1431589.142 |
| 557 | 14311.5 | 782006.372 | 1431584.269 |
| 558 | 14321.5 | 782015.105 | 1431579.396 |
| 559 | 14331.5 | 782023.837 | 1431574.523 |
| 560 | 14341.5 | 782032.569 | 1431569.650 |
| 561 | 14351.5 | 782041.301 | 1431564.777 |
| 562 | 14361.5 | 782050.034 | 1431559.904 |
| 563 | 14371.5 | 782058.766 | 1431555.031 |
| 564 | 14381.5 | 782067.498 | 1431550.158 |
| 565 | 14391.5 | 782076.231 | 1431545.285 |
| 566 | 14401.5 | 782084.963 | 1431540.412 |
| 567 | 14411.5 | 782093.695 | 1431535.539 |
| 568 | 14421.5 | 782102.428 | 1431530.666 |
| 569 | 14431.5 | 782111.160 | 1431525.793 |
| 570 | 14441.5 | 782119.892 | 1431520.920 |
| 571 | 14451.5 | 782128.625 | 1431516.047 |
| 572 | 14461.5 | 782137.357 | 1431511.173 |
| 573 | 14471.5 | 782146.089 | 1431506.300 |
| 574 | 14481.5 | 782154.822 | 1431501.427 |
| 575 | 14491.5 | 782163.554 | 1431496.554 |
| 576 | 14501.5 | 782172.286 | 1431491.681 |
| 577 | 14511.5 | 782181.019 | 1431486.808 |

| SL No. | Chainage (m) | Easting-X | Northing-Y |
|---|---|---|---|
| 578 | 14521.5 | 782189.751 | 1431481.935 |
| 579 | 14531.5 | 782198.483 | 1431477.062 |
| 580 | 14541.5 | 782207.216 | 1431472.189 |
| 581 | 14551.5 | 782215.948 | 1431467.316 |
| 582 | 14561.5 | 782224.680 | 1431462.443 |
| 583 | 14571.5 | 782233.413 | 1431457.570 |
| 584 | 14581.5 | 782242.145 | 1431452.697 |
| 585 | 14591.5 | 782250.879 | 1431447.827 |
| 586 | 14601.5 | 782259.634 | 1431442.995 |
| 587 | 14611.5 | 782268.436 | 1431438.249 |
| 588 | 14621.5 | 782277.307 | 1431433.634 |
| 589 | 14631.5 | 782286.254 | 1431429.168 |
| 590 | 14641.5 | 782295.275 | 1431424.852 |
| 591 | 14651.5 | 782304.366 | 1431420.686 |
| 592 | 14661.5 | 782313.525 | 1431416.673 |
| 593 | 14671.5 | 782322.750 | 1431412.813 |
| 594 | 14681.5 | 782332.038 | 1431409.107 |
| 595 | 14691.5 | 782341.386 | 1431405.556 |
| 596 | 14701.5 | 782350.792 | 1431402.162 |
| 597 | 14711.5 | 782360.254 | 1431398.925 |
| 598 | 14721.5 | 782369.768 | 1431395.846 |
| 599 | 14731.5 | 782379.332 | 1431392.926 |
| 600 | 14741.5 | 782388.943 | 1431390.166 |
| 601 | 14751.5 | 782398.599 | 1431387.566 |
| 602 | 14761.5 | 782408.297 | 1431385.128 |
| 603 | 14771.5 | 782418.035 | 1431382.852 |
| 604 | 14781.5 | 782427.809 | 1431380.738 |
| 605 | 14791.5 | 782437.614 | 1431378.775 |
| 606 | 14801.5 | 782447.439 | 1431376.914 |
| 607 | 14811.5 | 782457.273 | 1431375.100 |
| 608 | 14821.5 | 782467.109 | 1431373.293 |
| 609 | 14831.5 | 782476.944 | 1431371.486 |
| 610 | 14841.5 | 782486.779 | 1431369.679 |
| 611 | 14851.5 | 782496.615 | 1431367.871 |
| 612 | 14861.5 | 782506.450 | 1431366.064 |
| 613 | 14871.5 | 782516.285 | 1431364.257 |
| 614 | 14881.5 | 782526.121 | 1431362.450 |
| 615 | 14891.5 | 782535.956 | 1431360.642 |
| 616 | 14901.5 | 782545.792 | 1431358.835 |
| 617 | 14911.5 | 782555.627 | 1431357.028 |
| 618 | 14921.5 | 782565.462 | 1431355.221 |
| 619 | 14931.5 | 782575.298 | 1431353.414 |
| 620 | 14941.5 | 782585.133 | 1431351.606 |
| 621 | 14951.5 | 782594.968 | 1431349.799 |
| 622 | 14961.5 | 782604.804 | 1431347.992 |
| 623 | 14971.5 | 782614.639 | 1431346.185 |
| 624 | 14981.5 | 782624.474 | 1431344.377 |
| 625 | 14991.5 | 782634.310 | 1431342.570 |
| 626 | 15001.5 | 782644.145 | 1431340.763 |
| 627 | 15011.5 | 782653.980 | 1431338.956 |
| 628 | 15021.5 | 782663.816 | 1431337.149 |
| 629 | 15031.5 | 782673.651 | 1431335.341 |
| 630 | 15041.5 | 782683.486 | 1431333.534 |

| SL No. | Chainage (m) | Easting-X | Northing-Y |
|---|---|---|---|
| 631 | 15051.5 | 782693.322 | 1431331.727 |
| 632 | 15061.5 | 782703.157 | 1431329.920 |
| 633 | 15071.5 | 782712.992 | 1431328.112 |
| 634 | 15081.5 | 782722.828 | 1431326.305 |
| 635 | 15091.5 | 782732.663 | 1431324.498 |
| 636 | 15101.5 | 782742.498 | 1431322.691 |
| 637 | 15111.5 | 782752.334 | 1431320.884 |
| 638 | 15121.5 | 782762.169 | 1431319.076 |
| 639 | 15131.5 | 782772.004 | 1431317.269 |
| 640 | 15141.5 | 782781.840 | 1431315.462 |
| 641 | 15151.5 | 782791.675 | 1431313.655 |
| 642 | 15161.5 | 782801.510 | 1431311.847 |
| 643 | 15171.5 | 782811.346 | 1431310.040 |
| 644 | 15181.5 | 782821.181 | 1431308.233 |
| 645 | 15191.5 | 782831.016 | 1431306.426 |
| 646 | 15201.5 | 782840.852 | 1431304.619 |
| 647 | 15211.5 | 782850.687 | 1431302.811 |
| 648 | 15221.5 | 782860.522 | 1431301.004 |
| 649 | 15231.5 | 782870.358 | 1431299.197 |
| 650 | 15241.5 | 782880.193 | 1431297.390 |
| 651 | 15251.5 | 782890.028 | 1431295.582 |
| 652 | 15261.5 | 782899.864 | 1431293.775 |
| 653 | 15271.5 | 782909.699 | 1431291.968 |
| 654 | 15281.5 | 782919.534 | 1431290.161 |
| 655 | 15291.5 | 782929.370 | 1431288.354 |
| 656 | 15301.5 | 782939.205 | 1431286.546 |
| 657 | 15311.5 | 782949.041 | 1431284.739 |
| 658 | 15321.5 | 782958.876 | 1431282.932 |
| 659 | 15331.5 | 782968.711 | 1431281.125 |
| 660 | 15341.5 | 782978.547 | 1431279.317 |
| 661 | 15351.5 | 782988.382 | 1431277.510 |
| 662 | 15361.5 | 782998.217 | 1431275.703 |
| 663 | 15371.5 | 783008.053 | 1431273.896 |
| 664 | 15381.5 | 783017.888 | 1431272.089 |
| 665 | 15391.5 | 783027.723 | 1431270.281 |
| 666 | 15401.5 | 783037.559 | 1431268.474 |
| 667 | 15411.5 | 783047.394 | 1431266.667 |
| 668 | 15421.5 | 783057.229 | 1431264.860 |
| 669 | 15431.5 | 783067.065 | 1431263.052 |
| 670 | 15441.5 | 783076.900 | 1431261.245 |
| 671 | 15451.5 | 783086.735 | 1431259.438 |
| 672 | 15461.5 | 783096.571 | 1431257.630 |
| 673 | 15471.5 | 783106.400 | 1431255.791 |
| 674 | 15481.5 | 783116.208 | 1431253.842 |
| 675 | 15491.5 | 783125.976 | 1431251.703 |
| 676 | 15501.5 | 783135.689 | 1431249.324 |
| 677 | 15511.5 | 783145.339 | 1431246.703 |
| 678 | 15521.5 | 783154.921 | 1431243.842 |
| 679 | 15531.5 | 783164.428 | 1431240.742 |
| 680 | 15541.5 | 783173.855 | 1431237.405 |
| 681 | 15551.5 | 783183.195 | 1431233.834 |
| 682 | 15561.5 | 783192.443 | 1431230.030 |
| 683 | 15571.5 | 783201.593 | 1431225.997 |

| SL No. | Chainage (m) | Easting-X | Northing-Y |
|---|---|---|---|
| 684 | 15581.5 | 783210.640 | 1431221.736 |
| 685 | 15591.5 | 783219.577 | 1431217.250 |
| 686 | 15601.5 | 783228.399 | 1431212.542 |
| 687 | 15611.5 | 783237.101 | 1431207.615 |
| 688 | 15621.5 | 783245.676 | 1431202.472 |
| 689 | 15631.5 | 783254.121 | 1431197.117 |
| 690 | 15641.5 | 783262.429 | 1431191.551 |
| 691 | 15651.5 | 783270.596 | 1431185.780 |
| 692 | 15661.5 | 783278.615 | 1431179.807 |
| 693 | 15671.5 | 783286.483 | 1431173.635 |
| 694 | 15681.5 | 783294.194 | 1431167.268 |
| 695 | 15691.5 | 783301.743 | 1431160.711 |
| 696 | 15701.5 | 783309.127 | 1431153.967 |
| 697 | 15711.5 | 783316.339 | 1431147.040 |
| 698 | 15721.5 | 783323.376 | 1431139.936 |
| 699 | 15731.5 | 783330.233 | 1431132.657 |
| 700 | 15741.5 | 783336.906 | 1431125.210 |
| 701 | 15751.5 | 783343.391 | 1431117.598 |
| 702 | 15761.5 | 783349.683 | 1431109.826 |
| 703 | 15771.5 | 783355.779 | 1431101.899 |
| 704 | 15781.5 | 783361.676 | 1431093.823 |
| 705 | 15791.5 | 783367.368 | 1431085.601 |
| 706 | 15801.5 | 783372.853 | 1431077.240 |
| 707 | 15811.5 | 783378.128 | 1431068.745 |
| 708 | 15821.5 | 783383.188 | 1431060.120 |
| 709 | 15831.5 | 783388.031 | 1431051.371 |
| 710 | 15841.5 | 783392.654 | 1431042.504 |
| 711 | 15851.5 | 783397.054 | 1431033.525 |
| 712 | 15861.5 | 783401.228 | 1431024.438 |
| 713 | 15871.5 | 783405.174 | 1431015.249 |
| 714 | 15881.5 | 783408.889 | 1431005.965 |
| 715 | 15891.5 | 783412.370 | 1430996.591 |
| 716 | 15901.5 | 783415.616 | 1430987.133 |
| 717 | 15911.5 | 783418.625 | 1430977.596 |
| 718 | 15921.5 | 783421.394 | 1430967.988 |
| 719 | 15931.5 | 783423.922 | 1430958.313 |
| 720 | 15941.5 | 783426.208 | 1430948.578 |
| 721 | 15951.5 | 783428.257 | 1430938.790 |
| 722 | 15961.5 | 783430.128 | 1430928.967 |
| 723 | 15971.5 | 783431.903 | 1430919.126 |
| 724 | 15981.5 | 783433.655 | 1430909.281 |
| 725 | 15991.5 | 783435.408 | 1430899.435 |
| 726 | 16000.0 | 783436.904 | 1430891.028 |

## Centerline Coordinates to Approach to TBM tunnel Centre Line Tube-I ( LHS)

| SL No. | Chainage (m) | Easting-X | Northing-Y |
|---|---|---|---|
| 1 | 15+991 | 783435.279 | 1430900.169 |
| 2 | 16+001 | 783437.066 | 1430890.330 |
| 3 | 16+011 | 783438.852 | 1430880.491 |
| 4 | 16+021 | 783440.639 | 1430870.652 |
| 5 | 16+031 | 783442.425 | 1430860.813 |
| 6 | 16+041 | 783444.212 | 1430850.974 |
| 7 | 16+051 | 783445.998 | 1430841.135 |
| 8 | 16+061 | 783447.785 | 1430831.295 |
| 9 | 16+071 | 783449.571 | 1430821.456 |
| 10 | 16+081 | 783451.357 | 1430811.617 |
| 11 | 16+091 | 783453.144 | 1430801.778 |
| 12 | 16+101 | 783454.930 | 1430791.939 |
| 13 | 16+111 | 783456.717 | 1430782.100 |
| 14 | 16+121 | 783458.503 | 1430772.261 |
| 15 | 16+131 | 783460.290 | 1430762.422 |
| 16 | 16+141 | 783462.139 | 1430752.594 |
| 17 | 16+151 | 783464.250 | 1430742.820 |
| 18 | 16+161 | 783466.835 | 1430733.162 |
| 19 | 16+171 | 783470.100 | 1430723.713 |
| 20 | 16+181 | 783474.231 | 1430714.611 |
| 21 | 16+191 | 783479.329 | 1430706.014 |
| 22 | 16+201 | 783485.348 | 1430698.035 |
| 23 | 16+211 | 783492.216 | 1430690.773 |
| 24 | 16+221 | 783499.846 | 1430684.317 |
| 25 | 16+231 | 783508.145 | 1430678.747 |
| 26 | 16+241 | 783517.010 | 1430674.131 |
| 27 | 16+251 | 783526.333 | 1430670.527 |
| 28 | 16+261 | 783535.997 | 1430667.979 |
| 29 | 16+271 | 783545.885 | 1430666.518 |
| 30 | 16+281 | 783555.873 | 1430666.163 |
| 31 | 16+291 | 783565.840 | 1430666.918 |
| 32 | 16+301 | 783575.662 | 1430668.766 |
| 33 | 16+311 | 783585.258 | 1430671.567 |
| 34 | 16+321 | 783594.615 | 1430675.092 |
| 35 | 16+331 | 783603.769 | 1430679.116 |
| 36 | 16+341 | 783612.790 | 1430683.429 |
| 37 | 16+351 | 783621.768 | 1430687.834 |
| 38 | 16+361 | 783630.744 | 1430692.241 |
| 39 | 16+371 | 783639.721 | 1430696.649 |
| 40 | 16+381 | 783648.697 | 1430701.056 |
| 41 | 16+391 | 783657.673 | 1430705.464 |
| 42 | 16+401 | 783666.650 | 1430709.871 |
| 43 | 16+411 | 783675.626 | 1430714.279 |

| | | | |
|---|---|---|---|
| 44 | 16+421 | 783684.602 | 1430718.686 |
| 45 | 16+431 | 783693.579 | 1430723.093 |
| 46 | 16+441 | 783702.587 | 1430727.436 |
| 47 | 16+451 | 783711.711 | 1430731.526 |
| 48 | 16+461 | 783721.028 | 1430735.155 |
| 49 | 16+471 | 783730.581 | 1430738.102 |
| 50 | 16+481 | 783740.367 | 1430740.135 |
| 51 | 16+491 | 783750.317 | 1430741.086 |
| 52 | 16+501 | 783760.310 | 1430740.927 |
| 53 | 16+511 | 783770.225 | 1430739.661 |
| 54 | 16+521 | 783779.937 | 1430737.304 |
| 55 | 16+531 | 783789.329 | 1430733.885 |
| 56 | 16+541 | 783798.284 | 1430729.445 |
| 57 | 16+551 | 783806.691 | 1430724.039 |
| 58 | 16+561 | 783814.447 | 1430717.735 |
| 59 | 16+571 | 783821.485 | 1430710.637 |
| 60 | 16+581 | 783827.872 | 1430702.946 |
| 61 | 16+591 | 783833.739 | 1430694.849 |
| 62 | 16+601 | 783839.246 | 1430686.503 |
| 63 | 16+611 | 783844.572 | 1430678.039 |
| 64 | 16+621 | 783849.869 | 1430669.558 |
| 65 | 16+631 | 783855.167 | 1430661.076 |
| 66 | 16+641 | 783860.465 | 1430652.595 |
| 67 | 16+651 | 783865.762 | 1430644.113 |
| 68 | 16+661 | 783871.060 | 1430635.632 |
| 69 | 16+671 | 783876.357 | 1430627.150 |
| 70 | 16+681 | 783881.655 | 1430618.669 |
| 71 | 16+691 | 783886.953 | 1430610.187 |
| 72 | 16+701 | 783892.250 | 1430601.706 |
| 73 | 16+711 | 783897.548 | 1430593.224 |
| 74 | 16+721 | 783902.845 | 1430584.743 |
| 75 | 16+731 | 783908.143 | 1430576.261 |
| 76 | 16+741 | 783913.441 | 1430567.780 |
| 77 | 16+745 | 783915.714 | 1430564.140 |

## Centerline Coordinates of Tube-II (RHS)

| SL No. | Chainage (m) | Easting-X | Northing-Y |
|---|---|---|---|
| 1 | 8750 | 780024.239 | 1436450.822 |
| 2 | 8760 | 780023.613 | 1436440.842 |
| 3 | 8770 | 780022.987 | 1436430.862 |
| 4 | 8780 | 780022.361 | 1436420.881 |
| 5 | 8790 | 780021.735 | 1436410.901 |
| 6 | 8800 | 780021.108 | 1436400.920 |
| 7 | 8810 | 780020.482 | 1436390.940 |
| 8 | 8820 | 780019.856 | 1436380.960 |

| SL No. | Chainage (m) | Easting-X | Northing-Y |
|---|---|---|---|
| 9 | 8830 | 780019.230 | 1436370.979 |
| 10 | 8840 | 780018.604 | 1436360.999 |
| 11 | 8850 | 780017.978 | 1436351.019 |
| 12 | 8860 | 780017.352 | 1436341.038 |
| 13 | 8870 | 780016.726 | 1436331.058 |
| 14 | 8880 | 780016.100 | 1436321.077 |
| 15 | 8890 | 780015.474 | 1436311.097 |
| 16 | 8900 | 780014.848 | 1436301.117 |
| 17 | 8910 | 780014.222 | 1436291.136 |
| 18 | 8920 | 780013.596 | 1436281.156 |
| 19 | 8930 | 780012.969 | 1436271.176 |
| 20 | 8940 | 780012.343 | 1436261.195 |
| 21 | 8950 | 780011.717 | 1436251.215 |
| 22 | 8960 | 780011.091 | 1436241.234 |
| 23 | 8970 | 780010.465 | 1436231.254 |
| 24 | 8980 | 780009.839 | 1436221.274 |
| 25 | 8990 | 780009.213 | 1436211.293 |
| 26 | 9000 | 780008.587 | 1436201.313 |
| 27 | 9010 | 780007.961 | 1436191.332 |
| 28 | 9020 | 780007.335 | 1436181.352 |
| 29 | 9030 | 780006.709 | 1436171.372 |
| 30 | 9040 | 780006.083 | 1436161.391 |
| 31 | 9050 | 780005.457 | 1436151.411 |
| 32 | 9060 | 780004.830 | 1436141.431 |
| 33 | 9070 | 780004.204 | 1436131.450 |
| 34 | 9080 | 780003.578 | 1436121.470 |
| 35 | 9090 | 780002.952 | 1436111.489 |
| 36 | 9100 | 780002.326 | 1436101.509 |
| 37 | 9110 | 780001.700 | 1436091.529 |
| 38 | 9120 | 780001.074 | 1436081.548 |
| 39 | 9130 | 780000.448 | 1436071.568 |
| 40 | 9140 | 779999.822 | 1436061.587 |
| 41 | 9150 | 779999.196 | 1436051.607 |
| 42 | 9160 | 779998.570 | 1436041.627 |
| 43 | 9170 | 779997.944 | 1436031.646 |
| 44 | 9180 | 779997.318 | 1436021.666 |
| 45 | 9190 | 779996.692 | 1436011.686 |
| 46 | 9200 | 779996.065 | 1436001.705 |
| 47 | 9210 | 779995.439 | 1435991.725 |
| 48 | 9220 | 779994.813 | 1435981.744 |
| 49 | 9230 | 779994.187 | 1435971.764 |
| 50 | 9240 | 779993.561 | 1435961.784 |
| 51 | 9250 | 779992.935 | 1435951.803 |
| 52 | 9260 | 779992.309 | 1435941.823 |
| 53 | 9270 | 779991.683 | 1435931.843 |
| 54 | 9280 | 779991.057 | 1435921.862 |
| 55 | 9290 | 779990.431 | 1435911.882 |
| 56 | 9300 | 779989.805 | 1435901.901 |
| 57 | 9310 | 779989.179 | 1435891.921 |
| 58 | 9320 | 779988.553 | 1435881.941 |
| 59 | 9330 | 779987.926 | 1435871.960 |
| 60 | 9340 | 779987.300 | 1435861.980 |
| 61 | 9350 | 779986.675 | 1435851.999 |

| SL No. | Chainage (m) | Easting-X | Northing-Y |
|---|---|---|---|
| 62 | 9360 | 779986.054 | 1435842.019 |
| 63 | 9370 | 779985.444 | 1435832.037 |
| 64 | 9380 | 779984.854 | 1435822.055 |
| 65 | 9390 | 779984.290 | 1435812.071 |
| 66 | 9400 | 779983.760 | 1435802.085 |
| 67 | 9410 | 779983.270 | 1435792.097 |
| 68 | 9420 | 779982.829 | 1435782.107 |
| 69 | 9430 | 779982.442 | 1435772.114 |
| 70 | 9440 | 779982.119 | 1435762.119 |
| 71 | 9450 | 779981.865 | 1435752.123 |
| 72 | 9460 | 779981.688 | 1435742.124 |
| 73 | 9470 | 779981.593 | 1435732.125 |
| 74 | 9480 | 779981.582 | 1435722.125 |
| 75 | 9490 | 779981.655 | 1435712.125 |
| 76 | 9500 | 779981.810 | 1435702.126 |
| 77 | 9510 | 779982.049 | 1435692.129 |
| 78 | 9520 | 779982.372 | 1435682.134 |
| 79 | 9530 | 779982.777 | 1435672.143 |
| 80 | 9540 | 779983.266 | 1435662.154 |
| 81 | 9550 | 779983.838 | 1435652.171 |
| 82 | 9560 | 779984.493 | 1435642.192 |
| 83 | 9570 | 779985.232 | 1435632.220 |
| 84 | 9580 | 779986.053 | 1435622.254 |
| 85 | 9590 | 779986.957 | 1435612.295 |
| 86 | 9600 | 779987.945 | 1435602.343 |
| 87 | 9610 | 779989.015 | 1435592.401 |
| 88 | 9620 | 779990.168 | 1435582.468 |
| 89 | 9630 | 779991.404 | 1435572.544 |
| 90 | 9640 | 779992.722 | 1435562.632 |
| 91 | 9650 | 779994.123 | 1435552.730 |
| 92 | 9660 | 779995.607 | 1435542.841 |
| 93 | 9670 | 779997.173 | 1435532.964 |
| 94 | 9680 | 779998.821 | 1435523.101 |
| 95 | 9690 | 780000.551 | 1435513.252 |
| 96 | 9700 | 780002.363 | 1435503.418 |
| 97 | 9710 | 780004.258 | 1435493.599 |
| 98 | 9720 | 780006.233 | 1435483.796 |
| 99 | 9730 | 780008.291 | 1435474.010 |
| 100 | 9740 | 780010.430 | 1435464.241 |
| 101 | 9750 | 780012.650 | 1435454.491 |
| 102 | 9760 | 780014.952 | 1435444.759 |
| 103 | 9770 | 780017.334 | 1435435.047 |
| 104 | 9780 | 780019.798 | 1435425.356 |
| 105 | 9790 | 780022.342 | 1435415.685 |
| 106 | 9800 | 780024.966 | 1435406.035 |
| 107 | 9810 | 780027.665 | 1435396.406 |
| 108 | 9820 | 780030.432 | 1435386.797 |
| 109 | 9830 | 780033.260 | 1435377.205 |
| 110 | 9840 | 780036.143 | 1435367.630 |
| 111 | 9850 | 780039.072 | 1435358.068 |
| 112 | 9860 | 780042.040 | 1435348.519 |
| 113 | 9870 | 780045.042 | 1435338.980 |
| 114 | 9880 | 780048.070 | 1435329.450 |

| SL No. | Chainage (m) | Easting-X | Northing-Y |
|---|---|---|---|
| 115 | 9890 | 780051.117 | 1435319.925 |
| 116 | 9900 | 780054.176 | 1435310.404 |
| 117 | 9910 | 780057.240 | 1435300.885 |
| 118 | 9920 | 780060.305 | 1435291.367 |
| 119 | 9930 | 780063.369 | 1435281.848 |
| 120 | 9940 | 780066.434 | 1435272.329 |
| 121 | 9950 | 780069.499 | 1435262.810 |
| 122 | 9960 | 780072.564 | 1435253.291 |
| 123 | 9970 | 780075.628 | 1435243.773 |
| 124 | 9980 | 780078.693 | 1435234.254 |
| 125 | 9990 | 780081.758 | 1435224.735 |
| 126 | 10000 | 780084.823 | 1435215.216 |
| 127 | 10010 | 780087.887 | 1435205.697 |
| 128 | 10020 | 780090.952 | 1435196.179 |
| 129 | 10030 | 780094.017 | 1435186.660 |
| 130 | 10040 | 780097.082 | 1435177.141 |
| 131 | 10050 | 780100.146 | 1435167.622 |
| 132 | 10060 | 780103.211 | 1435158.104 |
| 133 | 10070 | 780106.276 | 1435148.585 |
| 134 | 10080 | 780109.341 | 1435139.066 |
| 135 | 10090 | 780112.405 | 1435129.547 |
| 136 | 10100 | 780115.470 | 1435120.028 |
| 137 | 10110 | 780118.535 | 1435110.510 |
| 138 | 10120 | 780121.600 | 1435100.991 |
| 139 | 10130 | 780124.664 | 1435091.472 |
| 140 | 10140 | 780127.729 | 1435081.953 |
| 141 | 10150 | 780130.794 | 1435072.434 |
| 142 | 10160 | 780133.858 | 1435062.916 |
| 143 | 10170 | 780136.923 | 1435053.397 |
| 144 | 10180 | 780139.988 | 1435043.878 |
| 145 | 10190 | 780143.053 | 1435034.359 |
| 146 | 10200 | 780146.117 | 1435024.840 |
| 147 | 10210 | 780149.182 | 1435015.322 |
| 148 | 10220 | 780152.247 | 1435005.803 |
| 149 | 10230 | 780155.312 | 1434996.284 |
| 150 | 10240 | 780158.376 | 1434986.765 |
| 151 | 10250 | 780161.441 | 1434977.247 |
| 152 | 10260 | 780164.506 | 1434967.728 |
| 153 | 10270 | 780167.571 | 1434958.209 |
| 154 | 10280 | 780170.635 | 1434948.690 |
| 155 | 10290 | 780173.700 | 1434939.171 |
| 156 | 10300 | 780176.765 | 1434929.653 |
| 157 | 10310 | 780179.830 | 1434920.134 |
| 158 | 10320 | 780182.894 | 1434910.615 |
| 159 | 10330 | 780185.959 | 1434901.096 |
| 160 | 10340 | 780189.024 | 1434891.577 |
| 161 | 10350 | 780192.089 | 1434882.059 |
| 162 | 10360 | 780195.153 | 1434872.540 |
| 163 | 10370 | 780198.218 | 1434863.021 |
| 164 | 10380 | 780201.283 | 1434853.502 |
| 165 | 10390 | 780204.348 | 1434843.983 |
| 166 | 10400 | 780207.412 | 1434834.465 |
| 167 | 10410 | 780210.477 | 1434824.946 |

| SL No. | Chainage (m) | Easting-X | Northing-Y |
|---|---|---|---|
| 168 | 10420 | 780213.542 | 1434815.427 |
| 169 | 10430 | 780216.607 | 1434805.908 |
| 170 | 10440 | 780219.671 | 1434796.390 |
| 171 | 10450 | 780222.736 | 1434786.871 |
| 172 | 10460 | 780225.801 | 1434777.352 |
| 173 | 10470 | 780228.865 | 1434767.833 |
| 174 | 10480 | 780231.930 | 1434758.314 |
| 175 | 10490 | 780234.995 | 1434748.796 |
| 176 | 10500 | 780238.060 | 1434739.277 |
| 177 | 10510 | 780241.124 | 1434729.758 |
| 178 | 10520 | 780244.189 | 1434720.239 |
| 179 | 10530 | 780247.254 | 1434710.720 |
| 180 | 10540 | 780250.319 | 1434701.202 |
| 181 | 10550 | 780253.383 | 1434691.683 |
| 182 | 10560 | 780256.448 | 1434682.164 |
| 183 | 10570 | 780259.513 | 1434672.645 |
| 184 | 10580 | 780262.578 | 1434663.126 |
| 185 | 10590 | 780265.642 | 1434653.608 |
| 186 | 10600 | 780268.707 | 1434644.089 |
| 187 | 10610 | 780271.772 | 1434634.570 |
| 188 | 10620 | 780274.837 | 1434625.051 |
| 189 | 10630 | 780277.901 | 1434615.532 |
| 190 | 10640 | 780280.966 | 1434606.014 |
| 191 | 10650 | 780284.031 | 1434596.495 |
| 192 | 10660 | 780287.096 | 1434586.976 |
| 193 | 10670 | 780290.160 | 1434577.457 |
| 194 | 10680 | 780293.225 | 1434567.939 |
| 195 | 10690 | 780296.290 | 1434558.420 |
| 196 | 10700 | 780299.355 | 1434548.901 |
| 197 | 10710 | 780302.419 | 1434539.382 |
| 198 | 10720 | 780305.484 | 1434529.863 |
| 199 | 10730 | 780308.549 | 1434520.345 |
| 200 | 10740 | 780311.613 | 1434510.826 |
| 201 | 10750 | 780314.678 | 1434501.307 |
| 202 | 10760 | 780317.743 | 1434491.788 |
| 203 | 10770 | 780320.808 | 1434482.269 |
| 204 | 10780 | 780323.872 | 1434472.751 |
| 205 | 10790 | 780326.937 | 1434463.232 |
| 206 | 10800 | 780330.002 | 1434453.713 |
| 207 | 10810 | 780333.067 | 1434444.194 |
| 208 | 10820 | 780336.131 | 1434434.675 |
| 209 | 10830 | 780339.196 | 1434425.157 |
| 210 | 10840 | 780342.261 | 1434415.638 |
| 211 | 10850 | 780345.326 | 1434406.119 |
| 212 | 10860 | 780348.390 | 1434396.600 |
| 213 | 10870 | 780351.455 | 1434387.082 |
| 214 | 10880 | 780354.520 | 1434377.563 |
| 215 | 10890 | 780357.585 | 1434368.044 |
| 216 | 10900 | 780360.649 | 1434358.525 |
| 217 | 10910 | 780363.714 | 1434349.006 |
| 218 | 10920 | 780366.779 | 1434339.488 |
| 219 | 10930 | 780369.844 | 1434329.969 |
| 220 | 10940 | 780372.908 | 1434320.450 |

| SL No. | Chainage (m) | Easting-X | Northing-Y |
|---|---|---|---|
| 221 | 10950 | 780375.973 | 1434310.931 |
| 222 | 10960 | 780379.038 | 1434301.412 |
| 223 | 10970 | 780382.103 | 1434291.894 |
| 224 | 10980 | 780385.167 | 1434282.375 |
| 225 | 10990 | 780388.232 | 1434272.856 |
| 226 | 11000 | 780391.297 | 1434263.337 |
| 227 | 11010 | 780394.361 | 1434253.818 |
| 228 | 11020 | 780397.426 | 1434244.300 |
| 229 | 11030 | 780400.491 | 1434234.781 |
| 230 | 11040 | 780403.556 | 1434225.262 |
| 231 | 11050 | 780406.620 | 1434215.743 |
| 232 | 11060 | 780409.685 | 1434206.225 |
| 233 | 11070 | 780412.750 | 1434196.706 |
| 234 | 11080 | 780415.815 | 1434187.187 |
| 235 | 11090 | 780418.879 | 1434177.668 |
| 236 | 11100 | 780421.944 | 1434168.149 |
| 237 | 11110 | 780425.009 | 1434158.631 |
| 238 | 11120 | 780428.074 | 1434149.112 |
| 239 | 11130 | 780431.138 | 1434139.593 |
| 240 | 11140 | 780434.203 | 1434130.074 |
| 241 | 11150 | 780437.268 | 1434120.555 |
| 242 | 11160 | 780440.333 | 1434111.037 |
| 243 | 11170 | 780443.397 | 1434101.518 |
| 244 | 11180 | 780446.462 | 1434091.999 |
| 245 | 11190 | 780449.527 | 1434082.480 |
| 246 | 11200 | 780452.592 | 1434072.961 |
| 247 | 11210 | 780455.656 | 1434063.443 |
| 248 | 11220 | 780458.721 | 1434053.924 |
| 249 | 11230 | 780461.786 | 1434044.405 |
| 250 | 11240 | 780464.851 | 1434034.886 |
| 251 | 11250 | 780467.915 | 1434025.368 |
| 252 | 11260 | 780470.980 | 1434015.849 |
| 253 | 11270 | 780474.045 | 1434006.330 |
| 254 | 11280 | 780477.109 | 1433996.811 |
| 255 | 11290 | 780480.174 | 1433987.292 |
| 256 | 11300 | 780483.239 | 1433977.774 |
| 257 | 11310 | 780486.304 | 1433968.255 |
| 258 | 11320 | 780489.368 | 1433958.736 |
| 259 | 11330 | 780492.433 | 1433949.217 |
| 260 | 11340 | 780495.498 | 1433939.698 |
| 261 | 11350 | 780498.563 | 1433930.180 |
| 262 | 11360 | 780501.627 | 1433920.661 |
| 263 | 11370 | 780504.692 | 1433911.142 |
| 264 | 11380 | 780507.757 | 1433901.623 |
| 265 | 11390 | 780510.822 | 1433892.104 |
| 266 | 11400 | 780513.886 | 1433882.586 |
| 267 | 11410 | 780516.951 | 1433873.067 |
| 268 | 11420 | 780520.016 | 1433863.548 |
| 269 | 11430 | 780523.081 | 1433854.029 |
| 270 | 11440 | 780526.145 | 1433844.511 |
| 271 | 11450 | 780529.210 | 1433834.992 |
| 272 | 11460 | 780532.275 | 1433825.473 |
| 273 | 11470 | 780535.340 | 1433815.954 |

| SL No. | Chainage (m) | Easting-X | Northing-Y |
|---|---|---|---|
| 274 | 11480 | 780538.404 | 1433806.435 |
| 275 | 11490 | 780541.469 | 1433796.917 |
| 276 | 11500 | 780544.534 | 1433787.398 |
| 277 | 11510 | 780547.599 | 1433777.879 |
| 278 | 11520 | 780550.663 | 1433768.360 |
| 279 | 11530 | 780553.728 | 1433758.841 |
| 280 | 11540 | 780556.793 | 1433749.323 |
| 281 | 11550 | 780559.857 | 1433739.804 |
| 282 | 11560 | 780562.922 | 1433730.285 |
| 283 | 11570 | 780565.987 | 1433720.766 |
| 284 | 11580 | 780569.052 | 1433711.247 |
| 285 | 11590 | 780572.116 | 1433701.729 |
| 286 | 11600 | 780575.181 | 1433692.210 |
| 287 | 11610 | 780578.246 | 1433682.691 |
| 288 | 11620 | 780581.311 | 1433673.172 |
| 289 | 11630 | 780584.375 | 1433663.653 |
| 290 | 11640 | 780587.440 | 1433654.135 |
| 291 | 11650 | 780590.505 | 1433644.616 |
| 292 | 11660 | 780593.570 | 1433635.097 |
| 293 | 11670 | 780596.634 | 1433625.578 |
| 294 | 11680 | 780599.699 | 1433616.060 |
| 295 | 11690 | 780602.764 | 1433606.541 |
| 296 | 11700 | 780605.829 | 1433597.022 |
| 297 | 11710 | 780608.893 | 1433587.503 |
| 298 | 11720 | 780611.958 | 1433577.984 |
| 299 | 11730 | 780615.023 | 1433568.466 |
| 300 | 11740 | 780618.088 | 1433558.947 |
| 301 | 11750 | 780621.152 | 1433549.428 |
| 302 | 11760 | 780624.217 | 1433539.909 |
| 303 | 11770 | 780627.282 | 1433530.390 |
| 304 | 11780 | 780630.347 | 1433520.872 |
| 305 | 11790 | 780633.411 | 1433511.353 |
| 306 | 11800 | 780636.476 | 1433501.834 |
| 307 | 11810 | 780639.541 | 1433492.315 |
| 308 | 11820 | 780642.605 | 1433482.796 |
| 309 | 11830 | 780645.670 | 1433473.278 |
| 310 | 11840 | 780648.735 | 1433463.759 |
| 311 | 11850 | 780651.800 | 1433454.240 |
| 312 | 11860 | 780654.864 | 1433444.721 |
| 313 | 11870 | 780657.929 | 1433435.203 |
| 314 | 11880 | 780660.994 | 1433425.684 |
| 315 | 11890 | 780664.059 | 1433416.165 |
| 316 | 11900 | 780667.123 | 1433406.646 |
| 317 | 11910 | 780670.188 | 1433397.127 |
| 318 | 11920 | 780673.253 | 1433387.609 |
| 319 | 11930 | 780676.318 | 1433378.090 |
| 320 | 11940 | 780679.382 | 1433368.571 |
| 321 | 11950 | 780682.447 | 1433359.052 |
| 322 | 11960 | 780685.512 | 1433349.533 |
| 323 | 11970 | 780688.577 | 1433340.015 |
| 324 | 11980 | 780691.641 | 1433330.496 |
| 325 | 11990 | 780694.706 | 1433320.977 |
| 326 | 12000 | 780697.771 | 1433311.458 |

| SL No. | Chainage (m) | Easting-X | Northing-Y |
|---|---|---|---|
| 327 | 12010 | 780700.836 | 1433301.939 |
| 328 | 12020 | 780703.900 | 1433292.421 |
| 329 | 12030 | 780706.965 | 1433282.902 |
| 330 | 12040 | 780710.030 | 1433273.383 |
| 331 | 12050 | 780713.095 | 1433263.864 |
| 332 | 12060 | 780716.159 | 1433254.346 |
| 333 | 12070 | 780719.224 | 1433244.827 |
| 334 | 12080 | 780722.289 | 1433235.308 |
| 335 | 12090 | 780725.353 | 1433225.789 |
| 336 | 12100 | 780728.418 | 1433216.270 |
| 337 | 12110 | 780731.483 | 1433206.752 |
| 338 | 12120 | 780734.548 | 1433197.233 |
| 339 | 12130 | 780737.612 | 1433187.714 |
| 340 | 12140 | 780740.677 | 1433178.195 |
| 341 | 12150 | 780743.742 | 1433168.676 |
| 342 | 12160 | 780746.807 | 1433159.158 |
| 343 | 12170 | 780749.871 | 1433149.639 |
| 344 | 12180 | 780752.936 | 1433140.120 |
| 345 | 12190 | 780756.001 | 1433130.601 |
| 346 | 12200 | 780759.066 | 1433121.082 |
| 347 | 12210 | 780762.130 | 1433111.564 |
| 348 | 12220 | 780765.195 | 1433102.045 |
| 349 | 12230 | 780768.260 | 1433092.526 |
| 350 | 12240 | 780771.325 | 1433083.007 |
| 351 | 12250 | 780774.389 | 1433073.489 |
| 352 | 12260 | 780777.454 | 1433063.970 |
| 353 | 12270 | 780780.519 | 1433054.451 |
| 354 | 12280 | 780783.584 | 1433044.932 |
| 355 | 12290 | 780786.648 | 1433035.413 |
| 356 | 12300 | 780789.713 | 1433025.895 |
| 357 | 12310 | 780792.778 | 1433016.376 |
| 358 | 12320 | 780795.843 | 1433006.857 |
| 359 | 12330 | 780798.907 | 1432997.338 |
| 360 | 12340 | 780801.972 | 1432987.819 |
| 361 | 12350 | 780805.037 | 1432978.301 |
| 362 | 12360 | 780808.101 | 1432968.782 |
| 363 | 12370 | 780811.166 | 1432959.263 |
| 364 | 12380 | 780814.231 | 1432949.744 |
| 365 | 12390 | 780817.296 | 1432940.225 |
| 366 | 12400 | 780820.360 | 1432930.707 |
| 367 | 12410 | 780823.425 | 1432921.188 |
| 368 | 12420 | 780826.490 | 1432911.669 |
| 369 | 12430 | 780829.555 | 1432902.150 |
| 370 | 12440 | 780832.619 | 1432892.631 |
| 371 | 12450 | 780835.684 | 1432883.113 |
| 372 | 12460 | 780838.749 | 1432873.594 |
| 373 | 12470 | 780841.814 | 1432864.075 |
| 374 | 12480 | 780844.878 | 1432854.556 |
| 375 | 12490 | 780847.943 | 1432845.038 |
| 376 | 12500 | 780851.008 | 1432835.519 |
| 377 | 12510 | 780854.073 | 1432826.000 |
| 378 | 12520 | 780857.137 | 1432816.481 |
| 379 | 12530 | 780860.202 | 1432806.962 |

| SL No. | Chainage (m) | Easting-X | Northing-Y |
|---|---|---|---|
| 380 | 12540 | 780863.267 | 1432797.444 |
| 381 | 12550 | 780866.332 | 1432787.925 |
| 382 | 12560 | 780869.396 | 1432778.406 |
| 383 | 12570 | 780872.461 | 1432768.887 |
| 384 | 12580 | 780875.526 | 1432759.368 |
| 385 | 12590 | 780878.591 | 1432749.850 |
| 386 | 12600 | 780881.655 | 1432740.331 |
| 387 | 12610 | 780884.720 | 1432730.812 |
| 388 | 12620 | 780887.785 | 1432721.293 |
| 389 | 12630 | 780890.849 | 1432711.774 |
| 390 | 12640 | 780893.914 | 1432702.256 |
| 391 | 12650 | 780896.979 | 1432692.737 |
| 392 | 12660 | 780900.044 | 1432683.218 |
| 393 | 12670 | 780903.108 | 1432673.699 |
| 394 | 12680 | 780906.173 | 1432664.181 |
| 395 | 12690 | 780909.238 | 1432654.662 |
| 396 | 12700 | 780912.303 | 1432645.143 |
| 397 | 12710 | 780915.367 | 1432635.624 |
| 398 | 12720 | 780918.432 | 1432626.105 |
| 399 | 12730 | 780921.497 | 1432616.587 |
| 400 | 12740 | 780924.562 | 1432607.068 |
| 401 | 12750 | 780927.626 | 1432597.549 |
| 402 | 12760 | 780930.691 | 1432588.030 |
| 403 | 12770 | 780933.756 | 1432578.511 |
| 404 | 12780 | 780936.821 | 1432568.993 |
| 405 | 12790 | 780939.885 | 1432559.474 |
| 406 | 12800 | 780942.950 | 1432549.955 |
| 407 | 12810 | 780946.015 | 1432540.436 |
| 408 | 12820 | 780949.080 | 1432530.917 |
| 409 | 12830 | 780952.144 | 1432521.399 |
| 410 | 12840 | 780955.209 | 1432511.880 |
| 411 | 12850 | 780958.274 | 1432502.361 |
| 412 | 12860 | 780961.339 | 1432492.842 |
| 413 | 12870 | 780964.403 | 1432483.324 |
| 414 | 12880 | 780967.468 | 1432473.805 |
| 415 | 12890 | 780970.533 | 1432464.286 |
| 416 | 12900 | 780973.597 | 1432454.767 |
| 417 | 12910 | 780976.662 | 1432445.248 |
| 418 | 12920 | 780979.727 | 1432435.730 |
| 419 | 12930 | 780982.792 | 1432426.211 |
| 420 | 12940 | 780985.856 | 1432416.692 |
| 421 | 12950 | 780988.921 | 1432407.173 |
| 422 | 12960 | 780991.986 | 1432397.654 |
| 423 | 12970 | 780995.051 | 1432388.136 |
| 424 | 12980 | 780998.115 | 1432378.617 |
| 425 | 12990 | 781001.180 | 1432369.098 |
| 426 | 13000 | 781004.245 | 1432359.579 |
| 427 | 13010 | 781007.310 | 1432350.060 |
| 428 | 13020 | 781010.374 | 1432340.542 |
| 429 | 13030 | 781013.439 | 1432331.023 |
| 430 | 13040 | 781016.504 | 1432321.504 |
| 431 | 13050 | 781019.569 | 1432311.985 |
| 432 | 13060 | 781022.633 | 1432302.467 |

| SL No. | Chainage (m) | Easting-X | Northing-Y |
|---|---|---|---|
| 433 | 13070 | 781025.698 | 1432292.948 |
| 434 | 13080 | 781028.763 | 1432283.429 |
| 435 | 13090 | 781031.828 | 1432273.910 |
| 436 | 13100 | 781034.892 | 1432264.391 |
| 437 | 13110 | 781037.957 | 1432254.873 |
| 438 | 13120 | 781041.033 | 1432245.357 |
| 439 | 13130 | 781044.139 | 1432235.852 |
| 440 | 13140 | 781047.297 | 1432226.364 |
| 441 | 13150 | 781050.526 | 1432216.899 |
| 442 | 13160 | 781053.847 | 1432207.467 |
| 443 | 13170 | 781057.280 | 1432198.075 |
| 444 | 13180 | 781060.845 | 1432188.732 |
| 445 | 13190 | 781064.562 | 1432179.449 |
| 446 | 13200 | 781068.449 | 1432170.235 |
| 447 | 13210 | 781072.525 | 1432161.104 |
| 448 | 13220 | 781076.809 | 1432152.068 |
| 449 | 13230 | 781081.313 | 1432143.140 |
| 450 | 13240 | 781086.039 | 1432134.328 |
| 451 | 13250 | 781090.984 | 1432125.636 |
| 452 | 13260 | 781096.144 | 1432117.071 |
| 453 | 13270 | 781101.518 | 1432108.637 |
| 454 | 13280 | 781107.100 | 1432100.341 |
| 455 | 13290 | 781112.888 | 1432092.186 |
| 456 | 13300 | 781118.878 | 1432084.179 |
| 457 | 13310 | 781125.066 | 1432076.324 |
| 458 | 13320 | 781131.448 | 1432068.626 |
| 459 | 13330 | 781138.022 | 1432061.090 |
| 460 | 13340 | 781144.781 | 1432053.721 |
| 461 | 13350 | 781151.722 | 1432046.523 |
| 462 | 13360 | 781158.842 | 1432039.501 |
| 463 | 13370 | 781166.134 | 1432032.659 |
| 464 | 13380 | 781173.595 | 1432026.001 |
| 465 | 13390 | 781181.221 | 1432019.532 |
| 466 | 13400 | 781189.006 | 1432013.256 |
| 467 | 13410 | 781196.945 | 1432007.176 |
| 468 | 13420 | 781205.027 | 1432001.287 |
| 469 | 13430 | 781213.235 | 1431995.577 |
| 470 | 13440 | 781221.555 | 1431990.028 |
| 471 | 13450 | 781229.970 | 1431984.625 |
| 472 | 13460 | 781238.466 | 1431979.352 |
| 473 | 13470 | 781247.031 | 1431974.191 |
| 474 | 13480 | 781255.652 | 1431969.123 |
| 475 | 13490 | 781264.317 | 1431964.131 |
| 476 | 13500 | 781273.015 | 1431959.197 |
| 477 | 13510 | 781281.734 | 1431954.301 |
| 478 | 13520 | 781290.464 | 1431949.424 |
| 479 | 13530 | 781299.197 | 1431944.551 |
| 480 | 13540 | 781307.929 | 1431939.678 |
| 481 | 13550 | 781316.661 | 1431934.805 |
| 482 | 13560 | 781325.394 | 1431929.932 |
| 483 | 13570 | 781334.126 | 1431925.059 |
| 484 | 13580 | 781342.858 | 1431920.186 |
| 485 | 13590 | 781351.591 | 1431915.313 |

| SL No. | Chainage (m) | Easting-X | Northing-Y |
|---|---|---|---|
| 486 | 13600 | 781360.323 | 1431910.440 |
| 487 | 13610 | 781369.055 | 1431905.567 |
| 488 | 13620 | 781377.788 | 1431900.694 |
| 489 | 13630 | 781386.520 | 1431895.821 |
| 490 | 13640 | 781395.252 | 1431890.948 |
| 491 | 13650 | 781403.985 | 1431886.075 |
| 492 | 13660 | 781412.717 | 1431881.202 |
| 493 | 13670 | 781421.449 | 1431876.329 |
| 494 | 13680 | 781430.182 | 1431871.456 |
| 495 | 13690 | 781438.914 | 1431866.583 |
| 496 | 13700 | 781447.646 | 1431861.709 |
| 497 | 13710 | 781456.379 | 1431856.836 |
| 498 | 13720 | 781465.111 | 1431851.963 |
| 499 | 13730 | 781473.843 | 1431847.090 |
| 500 | 13740 | 781482.575 | 1431842.217 |
| 501 | 13750 | 781491.308 | 1431837.344 |
| 502 | 13760 | 781500.040 | 1431832.471 |
| 503 | 13770 | 781508.772 | 1431827.598 |
| 504 | 13780 | 781517.505 | 1431822.725 |
| 505 | 13790 | 781526.237 | 1431817.852 |
| 506 | 13800 | 781534.969 | 1431812.979 |
| 507 | 13810 | 781543.702 | 1431808.106 |
| 508 | 13820 | 781552.434 | 1431803.233 |
| 509 | 13830 | 781561.166 | 1431798.360 |
| 510 | 13840 | 781569.899 | 1431793.487 |
| 511 | 13850 | 781578.631 | 1431788.614 |
| 512 | 13860 | 781587.363 | 1431783.741 |
| 513 | 13870 | 781596.096 | 1431778.868 |
| 514 | 13880 | 781604.828 | 1431773.995 |
| 515 | 13890 | 781613.560 | 1431769.122 |
| 516 | 13900 | 781622.293 | 1431764.249 |
| 517 | 13910 | 781631.025 | 1431759.376 |
| 518 | 13920 | 781639.757 | 1431754.502 |
| 519 | 13930 | 781648.490 | 1431749.629 |
| 520 | 13940 | 781657.222 | 1431744.756 |
| 521 | 13950 | 781665.954 | 1431739.883 |
| 522 | 13960 | 781674.687 | 1431735.010 |
| 523 | 13970 | 781683.419 | 1431730.137 |
| 524 | 13980 | 781692.151 | 1431725.264 |
| 525 | 13990 | 781700.883 | 1431720.391 |
| 526 | 14000 | 781709.616 | 1431715.518 |
| 527 | 14010 | 781718.348 | 1431710.645 |
| 528 | 14020 | 781727.080 | 1431705.772 |
| 529 | 14030 | 781735.813 | 1431700.899 |
| 530 | 14040 | 781744.545 | 1431696.026 |
| 531 | 14050 | 781753.277 | 1431691.153 |
| 532 | 14060 | 781762.010 | 1431686.280 |
| 533 | 14070 | 781770.742 | 1431681.407 |
| 534 | 14080 | 781779.474 | 1431676.534 |
| 535 | 14090 | 781788.207 | 1431671.661 |
| 536 | 14100 | 781796.939 | 1431666.788 |
| 537 | 14110 | 781805.671 | 1431661.915 |
| 538 | 14120 | 781814.404 | 1431657.042 |

| SL No. | Chainage (m) | Easting-X | Northing-Y |
|---|---|---|---|
| 539 | 14130 | 781823.136 | 1431652.168 |
| 540 | 14140 | 781831.868 | 1431647.295 |
| 541 | 14150 | 781840.601 | 1431642.422 |
| 542 | 14160 | 781849.333 | 1431637.549 |
| 543 | 14170 | 781858.065 | 1431632.676 |
| 544 | 14180 | 781866.798 | 1431627.803 |
| 545 | 14190 | 781875.530 | 1431622.930 |
| 546 | 14200 | 781884.262 | 1431618.057 |
| 547 | 14210 | 781892.995 | 1431613.184 |
| 548 | 14220 | 781901.727 | 1431608.311 |
| 549 | 14230 | 781910.459 | 1431603.438 |
| 550 | 14240 | 781919.191 | 1431598.565 |
| 551 | 14250 | 781927.924 | 1431593.692 |
| 552 | 14260 | 781936.656 | 1431588.819 |
| 553 | 14270 | 781945.388 | 1431583.946 |
| 554 | 14280 | 781954.121 | 1431579.073 |
| 555 | 14290 | 781962.853 | 1431574.200 |
| 556 | 14300 | 781971.585 | 1431569.327 |
| 557 | 14310 | 781980.318 | 1431564.454 |
| 558 | 14320 | 781989.050 | 1431559.581 |
| 559 | 14330 | 781997.782 | 1431554.708 |
| 560 | 14340 | 782006.515 | 1431549.835 |
| 561 | 14350 | 782015.247 | 1431544.961 |
| 562 | 14360 | 782023.979 | 1431540.088 |
| 563 | 14370 | 782032.712 | 1431535.215 |
| 564 | 14380 | 782041.444 | 1431530.342 |
| 565 | 14390 | 782050.176 | 1431525.469 |
| 566 | 14400 | 782058.909 | 1431520.596 |
| 567 | 14410 | 782067.641 | 1431515.723 |
| 568 | 14420 | 782076.373 | 1431510.850 |
| 569 | 14430 | 782085.106 | 1431505.977 |
| 570 | 14440 | 782093.838 | 1431501.104 |
| 571 | 14450 | 782102.570 | 1431496.231 |
| 572 | 14460 | 782111.303 | 1431491.358 |
| 573 | 14470 | 782120.035 | 1431486.485 |
| 574 | 14480 | 782128.767 | 1431481.612 |
| 575 | 14490 | 782137.500 | 1431476.739 |
| 576 | 14500 | 782146.232 | 1431471.866 |
| 577 | 14510 | 782154.964 | 1431466.993 |
| 578 | 14520 | 782163.696 | 1431462.120 |
| 579 | 14530 | 782172.429 | 1431457.247 |
| 580 | 14540 | 782181.161 | 1431452.374 |
| 581 | 14550 | 782189.893 | 1431447.501 |
| 582 | 14560 | 782198.626 | 1431442.628 |
| 583 | 14570 | 782207.358 | 1431437.754 |
| 584 | 14580 | 782216.090 | 1431432.881 |
| 585 | 14590 | 782224.823 | 1431428.008 |
| 586 | 14600 | 782233.555 | 1431423.135 |
| 587 | 14610 | 782242.291 | 1431418.269 |
| 588 | 14620 | 782251.053 | 1431413.450 |
| 589 | 14630 | 782259.867 | 1431408.726 |
| 590 | 14640 | 782268.754 | 1431404.140 |
| 591 | 14650 | 782277.715 | 1431399.704 |

| SL No. | Chainage (m) | Easting-X | Northing-Y |
|---|---|---|---|
| 592 | 14660 | 782286.750 | 1431395.417 |
| 593 | 14670 | 782295.854 | 1431391.281 |
| 594 | 14680 | 782305.026 | 1431387.297 |
| 595 | 14690 | 782314.264 | 1431383.467 |
| 596 | 14700 | 782323.564 | 1431379.792 |
| 597 | 14710 | 782332.923 | 1431376.272 |
| 598 | 14720 | 782342.341 | 1431372.908 |
| 599 | 14730 | 782351.813 | 1431369.702 |
| 600 | 14740 | 782361.337 | 1431366.654 |
| 601 | 14750 | 782370.910 | 1431363.765 |
| 602 | 14760 | 782380.531 | 1431361.037 |
| 603 | 14770 | 782390.195 | 1431358.468 |
| 604 | 14780 | 782399.901 | 1431356.062 |
| 605 | 14790 | 782409.646 | 1431353.817 |
| 606 | 14800 | 782419.427 | 1431351.735 |
| 607 | 14810 | 782429.237 | 1431349.796 |
| 608 | 14820 | 782439.065 | 1431347.949 |
| 609 | 14830 | 782448.899 | 1431346.139 |
| 610 | 14840 | 782458.735 | 1431344.332 |
| 611 | 14850 | 782468.570 | 1431342.525 |
| 612 | 14860 | 782478.406 | 1431340.718 |
| 613 | 14870 | 782488.241 | 1431338.910 |
| 614 | 14880 | 782498.076 | 1431337.103 |
| 615 | 14890 | 782507.912 | 1431335.296 |
| 616 | 14900 | 782517.747 | 1431333.489 |
| 617 | 14910 | 782527.582 | 1431331.682 |
| 618 | 14920 | 782537.418 | 1431329.875 |
| 619 | 14930 | 782547.253 | 1431328.068 |
| 620 | 14940 | 782557.089 | 1431326.261 |
| 621 | 14950 | 782566.924 | 1431324.454 |
| 622 | 14960 | 782576.759 | 1431322.647 |
| 623 | 14970 | 782586.595 | 1431320.840 |
| 624 | 14980 | 782596.430 | 1431319.033 |
| 625 | 14990 | 782606.265 | 1431317.226 |
| 626 | 15000 | 782616.101 | 1431315.419 |
| 627 | 15010 | 782625.936 | 1431313.612 |
| 628 | 15020 | 782635.772 | 1431311.805 |
| 629 | 15030 | 782645.607 | 1431309.998 |
| 630 | 15040 | 782655.442 | 1431308.191 |
| 631 | 15050 | 782665.278 | 1431306.383 |
| 632 | 15060 | 782675.113 | 1431304.576 |
| 633 | 15070 | 782684.948 | 1431302.769 |
| 634 | 15080 | 782694.784 | 1431300.962 |
| 635 | 15090 | 782704.619 | 1431299.155 |
| 636 | 15100 | 782714.454 | 1431297.348 |
| 637 | 15110 | 782724.290 | 1431295.541 |
| 638 | 15120 | 782734.125 | 1431293.734 |
| 639 | 15130 | 782743.961 | 1431291.927 |
| 640 | 15140 | 782753.796 | 1431290.120 |
| 641 | 15150 | 782763.631 | 1431288.313 |
| 642 | 15160 | 782773.467 | 1431286.506 |
| 643 | 15170 | 782783.302 | 1431284.699 |
| 644 | 15180 | 782793.137 | 1431282.892 |

| SL No. | Chainage (m) | Easting-X | Northing-Y |
|---|---|---|---|
| 645 | 15190 | 782802.973 | 1431281.085 |
| 646 | 15200 | 782812.808 | 1431279.278 |
| 647 | 15210 | 782822.644 | 1431277.471 |
| 648 | 15220 | 782832.479 | 1431275.664 |
| 649 | 15230 | 782842.314 | 1431273.856 |
| 650 | 15240 | 782852.150 | 1431272.049 |
| 651 | 15250 | 782861.985 | 1431270.242 |
| 652 | 15260 | 782871.820 | 1431268.435 |
| 653 | 15270 | 782881.656 | 1431266.628 |
| 654 | 15280 | 782891.491 | 1431264.821 |
| 655 | 15290 | 782901.327 | 1431263.014 |
| 656 | 15300 | 782911.162 | 1431261.207 |
| 657 | 15310 | 782920.997 | 1431259.400 |
| 658 | 15320 | 782930.833 | 1431257.593 |
| 659 | 15330 | 782940.668 | 1431255.786 |
| 660 | 15340 | 782950.503 | 1431253.979 |
| 661 | 15350 | 782960.339 | 1431252.172 |
| 662 | 15360 | 782970.174 | 1431250.365 |
| 663 | 15370 | 782980.010 | 1431248.558 |
| 664 | 15380 | 782989.845 | 1431246.751 |
| 665 | 15390 | 782999.680 | 1431244.944 |
| 666 | 15400 | 783009.516 | 1431243.137 |
| 667 | 15410 | 783019.351 | 1431241.329 |
| 668 | 15420 | 783029.186 | 1431239.522 |
| 669 | 15430 | 783039.022 | 1431237.715 |
| 670 | 15440 | 783048.857 | 1431235.908 |
| 671 | 15450 | 783058.693 | 1431234.101 |
| 672 | 15460 | 783068.528 | 1431232.294 |
| 673 | 15470 | 783078.360 | 1431230.467 |
| 674 | 15480 | 783088.173 | 1431228.547 |
| 675 | 15490 | 783097.952 | 1431226.453 |
| 676 | 15500 | 783107.676 | 1431224.124 |
| 677 | 15510 | 783117.340 | 1431221.553 |
| 678 | 15520 | 783126.936 | 1431218.740 |
| 679 | 15530 | 783136.459 | 1431215.689 |
| 680 | 15540 | 783145.902 | 1431212.401 |
| 681 | 15550 | 783155.261 | 1431208.877 |
| 682 | 15560 | 783164.528 | 1431205.121 |
| 683 | 15570 | 783173.699 | 1431201.134 |
| 684 | 15580 | 783182.767 | 1431196.920 |
| 685 | 15590 | 783191.727 | 1431192.480 |
| 686 | 15600 | 783200.573 | 1431187.817 |
| 687 | 15610 | 783209.300 | 1431182.935 |
| 688 | 15620 | 783217.902 | 1431177.836 |
| 689 | 15630 | 783226.374 | 1431172.523 |
| 690 | 15640 | 783234.710 | 1431167.001 |
| 691 | 15650 | 783242.906 | 1431161.272 |
| 692 | 15660 | 783250.956 | 1431155.339 |
| 693 | 15670 | 783258.855 | 1431149.208 |
| 694 | 15680 | 783266.599 | 1431142.881 |
| 695 | 15690 | 783274.182 | 1431136.362 |
| 696 | 15700 | 783281.599 | 1431129.655 |
| 697 | 15710 | 783288.847 | 1431122.766 |

| SL No. | Chainage (m) | Easting-X | Northing-Y |
|---|---|---|---|
| 698 | 15720 | 783295.920 | 1431115.697 |
| 699 | 15730 | 783302.814 | 1431108.454 |
| 700 | 15740 | 783309.525 | 1431101.041 |
| 701 | 15750 | 783316.049 | 1431093.462 |
| 702 | 15760 | 783322.381 | 1431085.723 |
| 703 | 15770 | 783328.518 | 1431077.827 |
| 704 | 15780 | 783334.455 | 1431069.781 |
| 705 | 15790 | 783340.190 | 1431061.589 |
| 706 | 15800 | 783345.717 | 1431053.256 |
| 707 | 15810 | 783351.035 | 1431044.787 |
| 708 | 15820 | 783356.140 | 1431036.189 |
| 709 | 15830 | 783361.028 | 1431027.465 |
| 710 | 15840 | 783365.696 | 1431018.622 |
| 711 | 15850 | 783370.142 | 1431009.665 |
| 712 | 15860 | 783374.362 | 1431000.599 |
| 713 | 15870 | 783378.355 | 1430991.431 |
| 714 | 15880 | 783382.117 | 1430982.166 |
| 715 | 15890 | 783385.646 | 1430972.810 |
| 716 | 15900 | 783388.941 | 1430963.368 |
| 717 | 15910 | 783391.998 | 1430953.847 |
| 718 | 15920 | 783394.816 | 1430944.253 |
| 719 | 15930 | 783397.394 | 1430934.591 |
| 720 | 15940 | 783399.729 | 1430924.868 |
| 721 | 15950 | 783401.832 | 1430915.092 |
| 722 | 15960 | 783403.767 | 1430905.281 |
| 723 | 15970 | 783405.615 | 1430895.453 |
| 724 | 15980 | 783407.418 | 1430885.781 |

## Centerline Coordinates to Approach to TBM tunnel Centre Line Tube-II ( RHS)

| SL No. | Chainage (m) | Easting-X | Northing-Y |
|---|---|---|---|
| 1 | 15+974 | 783406.327 | 1430891.637 |
| 2 | 15+984 | 783408.159 | 1430881.807 |
| 3 | 15+994 | 783409.999 | 1430871.978 |
| 4 | 16+004 | 783411.967 | 1430862.173 |
| 5 | 16+014 | 783414.098 | 1430852.403 |
| 6 | 16+024 | 783416.391 | 1430842.670 |
| 7 | 16+034 | 783418.846 | 1430832.976 |
| 8 | 16+044 | 783421.463 | 1430823.324 |
| 9 | 16+054 | 783424.240 | 1430813.718 |
| 10 | 16+064 | 783427.176 | 1430804.159 |
| 11 | 16+074 | 783430.272 | 1430794.650 |
| 12 | 16+084 | 783433.517 | 1430785.191 |
| 13 | 16+094 | 783436.797 | 1430775.744 |
| 14 | 16+104 | 783440.076 | 1430766.298 |
| 15 | 16+114 | 783443.356 | 1430756.851 |
| 16 | 16+124 | 783446.636 | 1430747.404 |
| 17 | 16+134 | 783449.926 | 1430737.961 |
| 18 | 16+144 | 783453.345 | 1430728.564 |
| 19 | 16+154 | 783457.074 | 1430719.285 |
| 20 | 16+164 | 783461.284 | 1430710.217 |
| 21 | 16+174 | 783466.135 | 1430701.475 |
| 22 | 16+184 | 783471.755 | 1430693.209 |
| 23 | 16+194 | 783478.152 | 1430685.527 |
| 24 | 16+204 | 783485.265 | 1430678.504 |
| 25 | 16+214 | 783493.027 | 1430672.205 |
| 26 | 16+224 | 783501.364 | 1430666.691 |
| 27 | 16+234 | 783510.198 | 1430662.014 |
| 28 | 16+244 | 783519.445 | 1430658.217 |
| 29 | 16+254 | 783529.018 | 1430655.338 |
| 30 | 16+264 | 783538.825 | 1430653.402 |
| 31 | 16+274 | 783548.773 | 1430652.430 |
| 32 | 16+284 | 783558.769 | 1430652.429 |
| 33 | 16+294 | 783568.718 | 1430653.400 |
| 34 | 16+304 | 783578.526 | 1430655.332 |
| 35 | 16+314 | 783588.120 | 1430658.141 |
| 36 | 16+324 | 783597.489 | 1430661.631 |
| 37 | 16+334 | 783606.664 | 1430665.608 |
| 38 | 16+344 | 783615.703 | 1430669.884 |
| 39 | 16+354 | 783624.684 | 1430674.282 |
| 40 | 16+364 | 783633.661 | 1430678.689 |
| 41 | 16+374 | 783642.637 | 1430683.097 |
| 42 | 16+384 | 783651.613 | 1430687.504 |
| 43 | 16+394 | 783660.592 | 1430691.908 |

| | | | |
|---|---|---|---|
| 44 | 16+404 | 783669.619 | 1430696.208 |
| 45 | 16+414 | 783678.785 | 1430700.206 |
| 46 | 16+424 | 783688.156 | 1430703.690 |
| 47 | 16+434 | 783697.768 | 1430706.436 |
| 48 | 16+444 | 783707.599 | 1430708.245 |
| 49 | 16+454 | 783717.561 | 1430709.064 |
| 50 | 16+464 | 783727.555 | 1430708.885 |
| 51 | 16+474 | 783737.482 | 1430707.708 |
| 52 | 16+484 | 783747.241 | 1430705.547 |
| 53 | 16+494 | 783756.736 | 1430702.422 |
| 54 | 16+504 | 783765.871 | 1430698.365 |
| 55 | 16+514 | 783774.556 | 1430693.416 |
| 56 | 16+524 | 783782.703 | 1430687.624 |
| 57 | 16+534 | 783790.272 | 1430681.093 |
| 58 | 16+544 | 783797.339 | 1430674.021 |
| 59 | 16+554 | 783804.033 | 1430666.593 |
| 60 | 16+564 | 783810.506 | 1430658.970 |
| 61 | 16+571 | 783814.777 | 1430653.856 |

**Centerline Coordinates of Entry Ramp 5 (Towards Hebbal Junction)**

| SL No. | Chainage (m) | Easting-X | Northing-Y |
|---|---|---|---|
| 1 | 200 | 780428.804 | 1435227.379 |
| 2 | 300 | 780344.868 | 1435282.159 |
| 3 | 407 | 780264.543 | 1435353.820 |
| 4 | 749 | 779938.122 | 1435503.527 |
| 5 | 1111 | 779958.490 | 1435881.885 |

**Centerline Coordinates of Entry Ramp 6 (Towards Silk Board Junction)**

| SL No. | Chainage (m) | Easting-X | Northing-Y |
|---|---|---|---|
| 1 | 200 | 780428.804 | 1435227.379 |
| 2 | 288 | 780367.466 | 1435290.543 |
| 3 | 755 | 779999.104 | 1435619.174 |
| 4 | 1412 | 780323.494 | 1436180.600 |

**Centerline Coordinates of Entry Ramp 7 (From Siddapura Rd Near Ashok Pillar-Lalbagh)**

| SL No. | Chainage (m) | Easting-X | Northing-Y |
|---|---|---|---|
| 1 | 103 | 780541.5164 | 1432537.721 |
| 2 | 259 | 780696.6105 | 1432581.948 |
| 3 | 438 | 780869.4694 | 1432680.291 |
| 4 | 1202 | 780629.0573 | 1433426.988 |

**Centerline Coordinates of Entry Ramp 8 From Sarjapur Road**

| SL No. | Chainage (m) | Easting-X | Northing-Y |
|---|---|---|---|
| 1 | 111 | 783731.5894 | 1430711.713 |
| 2 | 357 | 783931.1715 | 1430535.981 |
| 3 | 554 | 784104.612 | 1430661.395 |

**Centerline Coordinates of Exit Ramp 1 Towards Sarjapur**

| SL No. | Chainage (m) | Easting-X | Northing-Y |
|---|---|---|---|
| 1 | 163 | 783738.282 | 1430821.239 |

**Centerline Coordinates of Exit Ramp 2 (Towards Siddapura Rd Near Wilson Garden)**

| SL No. | Chainage (m) | Easting-X | Northing-Y |
|---|---|---|---|
| 1 | 219 | 780756.4279 | 1433325.05 |
| 2 | 840 | 780961.4981 | 1432688.122 |

**Centerline Coordinates of Exit Ramp 3 (From Silk Board Kr Circle On Seshadri Road)**

| SL No. | Chainage (m) | Easting-X | Northing-Y |
|---|---|---|---|
| 1 | 226 | 779994.638 | 1436454.519 |
| 2 | 670 | 779516.1063 | 1436462.991 |
| 3 | 1208 | 780020.5835 | 1436724.892 |

**Centerline Coordinates of Exit Ramp 4 (From Hebbal Towards Kr Circle On Seshadri Rd)**

| SL No. | Chainage (m) | Easting-X | Northing-Y |
|---|---|---|---|
| 1 | 230 | 780120.1464 | 1437021.354 |
| 2 | 931 | 780075.9933 | 1436315.249 |

## Annex – IV

## (Schedule-A)

## Environmental Clearances

The Tunnel project does not attract Environmental Clearance under EIA Notification, 2006. As per the Scheduled list of projects or activities requiring Prior Environmental Clearance, entry 7(f) of EIA Notification, 2006-page no. 21 dated 14.09.2006 and amended from time to time.

Further, SEIAA (State Environmental Impact Assessment Authority), Karnataka has already taken into cognizance the said notification and has provided that the proposed tunnel route does not attract Environment Clearance under EIA Notification, 2006. May kindly refer Letter No. SEIAA 80 MISC 2024 dated 26th November 2024 (copy enclosed).

**State Level Environment Impact Assessment Authority-Karnataka**

(Constituted by MoEF, Government of India, under section 3(3) of E(P) Act, 1986)

No. SEIAA 80 MISC 2024 Date: 26.11.2024

**To,**

The Chief Engineer
Bruhat Bengaluru Mahanagara Palike,
N.R. Square, Hudson Circle,
Bengaluru – 560002

**Respected Sir,**

**Sub:** Proposed tunnel route of distance 18 Km from Bangalore-Hebbal Esteem Mall Junction to Silk Board Junction-applicability of Environmental Clearance - Reg

**Ref:** BBMP Letter No. CE/BBMP/PR/1615/2024-25 dated 15.11.2024.

* * * * *

Inviting reference to the subject cited above and draft Detailed Project Report submitted vide reference captioned above, it is to inform that, the proposed tunnel route of distance 18 KM from Bangalore-Hebbal Esteem mall junction to Silk Board Junction does not attract the Environment Clearance under EIA Notification, 2006.

As per the scheduled list of Project or Activities requiring Prior Environment Clearance, entry 7(f) of EIA Notification, 2006 page No.21 dated 14.09.2006 and amended from time to time, expansion of National Highways upto 100 KMs involving additional Right of Way or Land acquisition upto 40 Mts on existing alignments and 60 Mts on re alignments or bypass is exempted from obtaining EC.

Extract of the EIA Notification, 2006 is enclosed for your kind information.

Yours faithfully,

**(Vijay Mohan Raj V)**
Member Secretary,
SEIAA, Karnataka.

Room No. 706, 7th Floor, 4th Gate, M.S. Building, Bangalore - 560 001 Phone : 080-22032497 Fax : 080-22254377
Website : http://environmentclearance.nic.in e-mail : msseiaakarnataka@gmail.com

# SCHEDULE - B

## Schedule B

**(See Clause 2.1)**

**Development of the Project Tunnel**

### 1. Development of the Project Tunnel

Design And Construction Of 3-Lane Underground Twin Tunnel Road from Hebbal Esteem Mall Junction (Km. 0+000) To Silk Board KSRP Junction (Km.16+745) Along With 3-Lane/2-Lane Entry & Exit Ramps Including Operation and Maintenance in Bengaluru City (North South Corridor) - On Modified BOOT. Package-2: Seshadri Road (Km 8.748) To Silk Board (Km 16.745) as described in Schedule-B and in Schedule-C.

### 2. 3-lane Underground Road Tunnel, shaft, Approach and Intermediate Ramps

2.1 Project shall include Construction of lower half (South portion) of the North-South corridor of the project and consists of twin tube tunnel (Tube 1 and Tube 2), Three TBM Launching and retrieval shafts, and Intermediate ramps at Racecourse, Lal Bagh and Silk Board Junction as described in Annexure-I of this Schedule-B and Annexure-I of Schedule-C.

2.2 Project Tunnel shall be completed by the Concessionaire in conformity with the Specifications and Standards set forth in **Annex-I** of **Schedule-D**.

## Annex – I

## (Schedule-B)

## Description of Project

### 1. Development of the Project

Development of Package 2 (Km 8+748 to Km 16+745) of the North-South corridor of the Project Tunnel which shall consist of twin tube tunnel, Three TBM Launching and retrieval shafts (Tube-1:Shaft-3 (Km 8+748 to Km 8+848), Tube-1:Shaft-4 (Km 12+625 to Km 12+725) , Tube-1:Shaft-5 (Km 15+990 to Km 16+090) and Tube-2:Shaft-3 (Km 8+725 to Km 8+824), Tube-2:Shaft-4 (Km 12+612 to Km 12+712), Tube-2:Shaft-5 (Km 15+968 to Km 16+070) Intermediate ramps at Racecourse, Lal Bagh and Silk Board Junction on Modified BOOT Mode

### 1.1 The significant parameters of the scope of the work involved in the contract are mentioned below:

| | |
|---|---|
| **Total project Length** | 7.997 km |
| **TBM Tunnel length** | Tube I: 7042 km & Tube II: 7044 km |
| **Maximum Design Speed** | 80 Kmph |
| **Lane Configuration** | 3 lanes |
| **Finished Tunnel Diameter** | 13.5 m Internal Dia. |
| **Cross passage** | 13 No. (Vehicular) |
| **Cross passage** | 08 Nos. (For Electrical Sub Stations) |
| **Shaft** | 3 Nos. for launching & retrieval of Tunnel boring machines |
| **Depth of Tunnel** | Tunnel crown varies 15m to 50m (1D to 4D) below the existing ground level. |

### 1.2 Tube-wise brief details are as follows:

| Description (LHS) | Details | Description (RHS) | Details |
|---|---|---|---|
| Start km | 8+748 | Start km | 8+725 |
| End km | 16+745 | End km | 16+571 |
| Length Tube 1 | 7997 m | Length Tube 2 | 7846 m |
| TBM Length Tube 1 | 7042 m | TBM Length Tube 2 | 7044 m |
| Shaft Length Tube 1 | 300 m | Shaft Length Tube 2 | 301 m |
| Cut and Cover Length Tube 1 | 425 m | Cut and Cover Length Tube 2 | 250 m |
| Open Cut Length Tube 1 | 230 m | Open Cut Length Tube 2 | 251 m |
| Shaft-3 | Km 8+748 to Km 8+848 | Shaft-3 | Km 8+725 to Km 8+824 |
| Shaft-4 | Km 12+625 to Km 12+725 | Shaft-4 | Km 12+612 to Km 12+712 |
| Shaft-5 | Km 15+990 to Km 16+090 | Shaft-5 | Km 15+968 to Km 16+070 |

### 1.3 Entry Exit details at Racecourse/Vidhan Saudha:

| Sr. No. | Location | Description | Length (m) | Direction Of Traffic | Lane Configuration |
|---|---|---|---|---|---|
| **Intermediate Ramps** | | | | | |
| 1 | Near Racecourse / Vidhan Saudha | Entry Ramp 5 into Main Tunnel | 1197 | From District Officer Road Towards Hebbal | 2 Lane |
| 2 | | Entry Ramp 6 into Main Tunnel | 1783 | From District Officer Road Towards Silk Board Junction | 2 Lane |
| 3 | | Exit Ramp 04 from Main Tunnel | 1141 | On Seshadri Road (Towards KR Circle) | 2 Lane |
| 4 | | Exit Ramp 03 from Main Tunnel | 1465 | On Seshadri Road (Towards KR Circle) | 2 Lane |

### 1.4 Ramps Details at Lalbagh Botanical Garden:

| Sr. No. | Location | Description | Length (m) | Direction Of Traffic | Lane Configuration |
|---|---|---|---|---|---|
| **Intermediate Ramps** | | | | | |
| 1 | Near Lalbagh | Entry Ramp 7 into Main Tunnel | 1416 | From Siddapura Road (Near Ashoka Pillar). | 2 Lane |
| 2 | | Exit Ramp 2 from Main Tunnel | 1081 | On Siddapura Road Near Wilson Garden | 2 Lane |

**1.5 Ramps Details at Silk Board Junction:**

| Sr. No. | Location | Description | New Length (m) | Direction Of Traffic | Lane Configuration |
|---|---|---|---|---|---|
| **Ramps at End of Main Tunnel** | | | | | |
| 1 | Silk Board | Exit Ramp 1 from Main Tunnel | 455 | On Sarjapur Road / HSR layout (Ring Road) | 2 Lane |
| 2 | | Entry Ramp 8 into Main Tunnel | 654 | From Sarjapur Road / HSR layout (Ring Road) | 2 Lane |

**Note: The above table shall be read along with alignment Plan.**

Entry & Exit ramps shall be provided as per **Appendix B-I**

**1.6 Width of Carriageway**

For different tunnel construction methods, including TBM Tunnel, Cut & Cover, NATM Tunnel, and Open Cut ramps, the carriageway width shall strictly adhere to the dimensions and specifications provided in the Typical Cross Section and outlined in clause 2.4.5 of Annexure I Schedule-B and attached in Appendix B-I (Drawings Volume) of Schedule B.

**1.7 Width of Median**

The width of Separator/ median excluding Kerb shyness shall be 1.0 meter as per TCS as per TCS as attached in Appendix B-I.

**1.8 Cross Passage:**

The minimum clear width of cross passage shall be 7.1 m, Carriageway 3.5 meters, 0.6 meter of edge strip, 0.5 meter of RCC crash barrier either side, 1.0 meter of walkway either side and fire check door at both ends of Cross passages. The cross passage will be with sump and without sump as per drainage design requirement. The cross passages are to be provided at regular interval of 500 m as specified in Annexure- B of IRC:SP:91-2019.

**1.9 Cross Passage (For Electrical Sub Stations)**

The minimum clear width of cross passage shall be 7.1 m.

**1.10 Ventilation Shaft:**

Vertical Ventilation Shafts shall be provided at the Intermodal hub locations to be constructed by the concessionaire as per the tender drawings to achieve fully transverse ventilation in the TBM tunnel and longitudinal ventilation in the NATM Tunnel and Box Tunnel in accordance with the standard and specification, schedule "D".

**1.10.1 Ventilation:** A transverse ventilation system shall be provided in TBM Tunnel and longitudinal Ventilation System shall be provided for NATM Tunnel and Box Tunnel. Ventilation system shall be provided as per the Technical Specifications and Guidelines for Road Tunnels IRC: SP: 91-2019, NFPA 502 (2017), PIARC Technical Committee C4 – Road Tunnels: Vehicle Emissions and Air Demand for Ventilation (2011).

**1.11 Lighting, Electrical and Mechanical facilities:**

The electrical and Mechanical works includes streetlights, Lighting in Open cut, Box tunnel, NATM tunnel and TBM Tunnel, Ventilation for Box Tunnel, NATM Tunnel & TBM Tunnel, Firefighting & firefighting installation, water sprinkling system & plumbing Drainage system shall be provided as per the Technical Specifications and Guidelines for Road Tunnels IRC: SP: 91-2019. An indicative plan is attached in **Appendix B-IV**.

Normal Lighting & Emergency Lighting in the Road tunnel shall be designed according to the Technical Specifications and CIE 88:2004 standard "Guide for the Lighting of Road Tunnels and Underpasses" for two- way traffic including Cable & cable laying, Main Electrical panel & Sub Panels, earthing of complete system, galvanized supporting structure and all other necessary accessories, etc. and as per the Guidelines for Road Tunnels IRC: SP: 91-2019. The light intensity of the entry and exit zones shall be adapted to the actual outside lighting level according to external conditions (day/night, regulation through measurement of luminous density).

Tunnel safety facilities such as CCTV- cameras, traffic lights, variable message signs, traffic loop detectors, emergency communications, alarm push buttons, fire detection systems etc. shall be provided as per the Technical Specifications and Guidelines for Road Tunnels IRC: SP: 91-2019.

### 1.12 Tunnel Drainage system

The tunnel shall be designed as a dry and drained tunnel. The drainage system of Main TBM Tunnel, NATM Tunnel, Cut & Cover & Open cut ramps should be as indicated in the cross section and Appendix B-III. The Concessionaire shall design the drainage along the Tunnel in such a way that the outfall of Tunnel drainage system to be connected with nearby municipal drainage system having adequate capacity as per requirement of Tunnel discharge. The drainage plan prepared by the Concessionaire shall be approved by IE and consented by concerned Government Authorities to connect the Tunnel drainage system with municipal drainage system.

For urban tunnel roadways and approach roads that are subjected to frequent passage of heavy motor vehicles—including buses, trucks, and emergency vehicles—the design and thickness of drain covers must be aligned with Class D400 to F900 of EN 124 or equivalent Indian standards. These classifications represent the heaviest permissible loads encountered in urban and industrial road environments.

Each cover and frame combination must be lab-tested for static and dynamic load-bearing performance to verify that it can safely handle:

- Axle loads up to 11.5 tonnes, as per IRC:6 or equivalent AASHTO standards.
- Wheel pressure and impact loading associated with sudden braking or turning of trucks and buses.

Furthermore, the design shall ensure:

- Minimal deflection (<1 mm under full load) to prevent rattling.
- Proper seating and locking to avoid displacement under impact.
- Corrosion protection through hot-dip galvanization (for steel) or bituminous/epoxy coating (for iron).

To ensure long-term performance, all covers installed in heavy-traffic tunnel sections must be periodically inspected for cracking, deflection, and corrosion—especially after monsoon or high-traffic events.

### 1.13 Project Facilities:

Project facilities shall be constructed in conformity with **Annexure-I** of Schedule C.

### 1.14 Other Features of project

#### 1.14.1 Typical Cross section

The cross section of the Main TBM Tunnel, NATM tunnel, Cut & Cover, Open Cut approach, Cross passages, Shafts, should be as indicated in **Appendix B-I.**

#### 1.14.2 Alignment Plan and longitudinal Section

The indicative Alignment Plan & Vertical profile of Tunnel Project which includes Main Tunnel, Ramps & intermediate ramps is given in **Appendix B-II.**

#### 1.14.3 Existing Road Connectivity

The provision of existing road connectivity shall be at approach of main Tunnel, entry ramps and exit ramps (near open cut area) as per indicative Alignment Plan & Vertical profile which is attached an **Appendix B-I.** The width of existing roads be maintained the same. The existing road connectivity shall be constructed with merging and diverging length at the location for the minimum lengths indicated below

| Sr. No. | Ramp | Existing Road | | Length | Remark |
|---|---|---|---|---|---|
| | | Start | End | | |
| 1 | Diversion road | 0+900 | 1+040 | 240 | Seshadri Road |
| 2 | Entry Ramp-7 Cut & cover | 0+130 | 0+325 | 195 | Siddapura Road (Near Ashoka Pillar) |
| 3 | Exit Ramp-1 Cut & cover | 0+120 | 0+250 | 130 | Towards Sarjapur Road |
| | Exit Ramp-1 Open cut | 0+250 | 0+455 | 205 | |
| 4 | Cut & Cover End of Main Tunnel Tube-1 | 16+500 | 16+600 | 100 | Towards Silk bord |
| | Open Cut End of Main Tunnel Tube-1 | 16+600 | 16+745 | 145 | |
| 5 | Entry Ramp-8 | 0+225 | 0+350 | 125 | Towards Sarjapur Road. |

**Note: 1. Length of the existing road connectivity given in the table above are minimum requirements. Further, all development of roads shall be done within the available ROW by providing cutting and filling. Change of Scope shall not be applicable for the increase in the length of roads provided in the table above.*

## 2. Geometric Design and General Features

### 2.1 General

Geometric design and the general features of the Project shall be in accordance with IRC: 86-2018 (GEOMETRIC DESIGN STANDARDS FOR URBAN ROADS AND STREETS), IRC: SP:91-2019 and others applicable National & Internation standards as per Schedule-D. Intermediate Sight distance (Desirable Minimum Sight Distance) shall be followed for design of vertical curves.

### 2.2 Design Speed

The minimum design speed shall be 80 kmph for the main TBM Tunnel & approaches and 50 kmph for intermediate ramps & approaches as per IRC:86:2018.

### 2.3 Vertical Gradient

The vertical profile of the project shall be as per the plan profile Annexed as Appendix -B-II of Volume-3 .

### 2.4 Pavement:

The loops, ramps, NATM and TBM tunnel shall be provided with rigid pavement. Pavement design shall be carried out in accordance with the provision of the IRC:58-2015 and other relevant Manual.

The minimum layer thickness for the pavement is mentioned below, however the concessionaire shall design the thickness and get it approved by Authority.

| Layer (IN NATM Tunnel) | Minimum Thickness (mm) |
|---|---|
| PQC | 250 |
| DLC | 150 |
| **Total Thickness** | **400** |

| Layer (IN TBM Tunnel) | Minimum Thickness (mm) |
|---|---|
| RCC Slab | 350 |
| Cement Concrete Wearing Coat | 75 |
| **Total Thickness** | **425** |

| Layer (in Cut & Cover and Open ramps) | Minimum Thickness (mm) |
|---|---|
| Cement Concrete Wearing coat over bottom slab | 75 |
| **Total Thickness** | **75** |

### 2.5 Design requirements

#### 2.5.1 Design Period and strategy

Rigid pavement shall be designed for a minimum design period of 30 years. Stage construction shall not be

permitted.

### 2.5.2 Design Traffic

Notwithstanding anything to the contrary contained in this Agreement or the Manual, the design of pavement shall be for a minimum design traffic of 75 million standard axles.

## 3. Right of Way

Details of the Right of Way along Project Tunnel are given in **Annexure II** of Schedule-A.

*Note: The concessionaire shall adopt prudent construction methodology and carry out construction with due care so that there shall be no damage to the structures/properties within/ outside the acquired ROW in the influence zone of the tunnel, otherwise, the cost of their repair/damages shall be borne by the concessionaire, wherever damages will be on account of the concessionaire.*

## 4. Refuge Parking

The Refuge Parking should be designed and constructed in accordance with relevant standards and specifications and should be provided at the locations as indicated below at the extreme left edge of the carriageway at Shaft Location. The width of refuge parking shall be minimum of 3.5m. The location of the Shaft is as under-

| | **Tube 1** | | **Tube 2** | |
|---|---|---|---|---|
| | **Start** | **End** | **Start** | **End** |
| **Shaft 3** | 8+748 | 8+848 | 8+725 | 8+824 |
| **Shaft 4** | 12+625 | 12+725 | 12+612 | 12+712 |
| **Shaft 5** | 15+990 | 16+090 | 15+968 | 16+070 |

Refuge Parking is shown in the plan at **Appendix B-VI**

## 5. Typical Cross Section (TCS) of the Project Tunnel

The Project Tunnel shall be constructed as per the Plan & profile and Typical Cross section attached in **Appendix B-I**. The Typical Cross Sections proposed in the different stretches of the Project Tunnel are given below.

| **Main Tunnel with Entry and Exits** | | | | | | |
|---|---|---|---|---|---|---|
| TBM Tunnel | | | | | | |
| **TBM Tunnel Tube 1 (Hebbal to Silk Borad)** | | | | | | |
| **Sr. No.** | **Chainage** | | **Length** | **TCS** | **TCS Type** | **Lane Configuration** |
| | **From** | **To** | | | | |
| **1** | 8+748 | 8+848 | 100 | SHAFT | TBM SHAFT | |
| **2** | 8+848 | 12+625 | 3777 | TCS-1 | TBM Tunnel | 3 Lane |
| **3** | 12+625 | 12+725 | 100 | SHAFT | TBM SHAFT | |
| **4** | 12+725 | 15+990 | 3265 | TCS-1 | TBM Tunnel | 3 Lane |
| **5** | 15+990 | 16+090 | 100 | SHAFT | TBM SHAFT | |
| **6** | 16+090 | 16+155 | 65 | TCS-6 | Cut and Cover | 3 Lane |
| **TBM Tunnel Tube 2 (Silk Borad to Hebbal)** | | | | | | |
| **1** | 8+725 | 8+824 | 99 | SHAFT | TBM SHAFT | |
| **2** | 8+824 | 12+612 | 3788 | TCS-1 | TBM Tunnel | 3 Lane |
| **3** | 12+612 | 12+712 | 100 | SHAFT | TBM SHAFT | |
| **4** | 12+712 | 15+968 | 3256 | TCS-1 | TBM Tunnel | 3 Lane |
| **5** | 15+968 | 16+070 | 102 | SHAFT | TBM SHAFT | |
| **6** | 16+070 | 16+140 | 70 | TCS-6 | Cut and Cover | 3 Lane |
| **At Silk Board Side** | | | | | | |
| **Portion Common to Tube-1 and Tube-2 At Silk Board Side** | | | | | | |
| **1** | **Tube-2 16+140** (Tube-1 16+155) | Tube-2 16+320 (Tube-1 16+315) | 180 | TCS-14 | Cut and Cover | 3+3 Lane |

| | | | | | | |
|---|---|---|---|---|---|---|
| **2** | Tube-2 16+320 (Tube-1 16+315) | Tube-2 16+350 (Tube-1 16+345) | 30 | TCS-10 | Open Cut | 3+3 Lane |
| **Tube 2 (Silk Board to Hebbal)** | | | | | | |
| **1** | 16+350 | 16+571 | 221 | TCS-4 | Open Cut | 2 Lane |
| **Tube 1 (Hebbal to Silk Board)** | | | | | | |
| **3** | 16+345 | 16+357 | 12 | TCS-02 | Open Cut | 3 Lane |
| **4** | 16+357 | 16+400 | 43 | TCS-4 | Open Cut | 2 Lane |
| **5** | 16+400 | 16+600 | 200 | TCS-03A | Cut and Cover | 2 Lane |
| **6** | 16+600 | 16+745 | 145 | TCS-4 | Open Cut | 2 Lane |
| **Intermediate Ramps** | | | | | | |
| **Exit and Entry Ramps at Silk Board.** | | | | | | |
| **Entry Ramp 8 (From Sarjapur Road)** | | | | | | |
| **1** | 0+000 | 0+190 | 190 | TCS-4 | Open Cut | 2 Lane |
| **2** | 0+190 | 0+390 | 200 | TCS-03A | Cut and Cover | 2 Lane |
| **3** | 0+390 | 0+654 | 264 | TCS-4 | Open Cut | 2 Lane |
| **Exit Ramp 1 (Towards Sarjapur Road)** | | | | | | |
| **1** | 0+000 | 0+050 | 50 | TCS-4 | Open Cut | 2 Lane |
| **2** | 0+050 | 0+250 | 200 | TCS-03A | Cut and Cover | 2 Lane |
| **3** | 0+250 | 0+455 | 205 | TCS-4 | Open Cut | 2 Lane |
| **At Racecourse** | | | | | | |
| **Freedom park / Seshadri Road ( Exit 3& 4)** | | | | | | |
| **Sr. No.** | **Chainage** | | **Length** | **TCS** | **TCS Type** | **Lane Configuration** |
| | **From** | **To** | | | | |
| **Common Ramp for Entry and Entry 6 from District Officer Road (CSI Hudson Memorial Church)** | | | | | | |
| **1** | 0+000 | 0+130 | 130 | TCS-02 | Open Cut | 3 Lane |
| **2** | 0+130 | 0+162 | 32 | TCS-06 | Cut and Cover | 3 Lane |
| **Entry Ramp 5 (Towards Hebbal Junction)** | | | | | | |
| **1** | 0+162 | 0+270 | 108 | TCS-03 | Cut and Cover | 2 Lane |
| **2** | 0+270 | 1+197 | 927 | TCS-05 | NATM Tunnel | 2 Lane |
| **Entry Ramp 6 (Towards Silk Board Junction)** | | | | | | |
| **1** | 0+162 | 0+270 | 108 | TCS-03 | Cut and Cover | 2 Lane |
| **2** | 0+270 | 1+783 | 1513 | TCS-05 | NATM Tunnel | 2 Lane |
| **Portion Common to Exit Ramp-5 & Exit Ramp 6** | | | | | | |
| **1** | 0+840 | 1+141 | 301 | TCS-02 | Open Cut | 3 Lane |
| **2** | 0+820 | 0+840 | 20 | TCS-06A | Cut and Cover | 3 Lane |
| **3** | 0+790 | 0+820 | 30 | TCS-06 | Cut and Cover | 3 Lane |
| **Exit Ramp-4 (From Hebbal Towards KR Circle On Seshadri Road)** | | | | | | |
| **1** | 0+000 | 0+610 | 610 | TCS-05 | NATM | 2 Lane |
| **2** | 0+610 | 0+790 | 180 | TCS-03 | Cut and Cover | 2 Lane |
| **Exit Ramp-3 (From Silk Board KR Circle On Seshadri Road )** | | | | | | |
| **1** | 0+000 | **0+575** | 575 | TCS-05 | NATM | 2 Lane |
| **2** | **0+575** | 1+465 | 890 | TCS-03 | Cut and Cover | 2 Lane |
| **At Lalbagh** | | | | | | |
| **Exit Ramp 2 (Towards Siddapura Road near Wilson Garden)** | | | | | | |
| **1** | 0+000 | 0+900 | 900 | TCS-05 | NATM Tunnel | 2 Lane |
| **2** | 0+900 | 0+960 | 60 | TCS-03 | Cut and Cover | 2 Lane |
| **3** | 0+960 | 1+081 | 121 | TCS-04 | Open Cut | 2 Lane |
| **Entry Ramp 7 (From Siddapura Road near Ashok Pillar)** | | | | | | |
| **1** | 0+000 | 0+130 | 130 | TCS-04 | Open Cut | 2 Lane |
| **2** | 0+130 | 0+160 | 30 | TCS-03A | Cut and Cover | 2 Lane |
| **3** | 0+160 | 0+410 | 250 | TCS-03 | Cut and Cover | 2 Lane |
| **4** | 0+410 | 1+416 | 1006 | TCS-05 | NATM | 2 Lane |

*Note:*

*(i) Any variations in the lengths specified in the above table shall not constitute a Change of Scope*

*(ii) Chainages may be adjusted according to the location of structures as per drawings.*

*(iii) Carriageway width tapering shall be provided as per manual mentioned in Schedule-D*

*(iv) Intermediate Sight Distance (Desirable Minimum Sight Distance) shall be followed for the design of all vertical curves (Summit and Valley Curves).*

## 6. Roadside Drainage

The Concessionaire shall design the drainage along the highway as per the drainage plan as per **Appendix B-III**. The provided drainage plans with the Schedules are indicative only. The Concessionaire shall prepare the proper drainage plan of the project on the basis of the contours of the area, outlet availability and discharge requirements including discharge at the outfall from drains of local bodies. The drainage plan prepared by the Concessionaire shall be approved by IE. The drainage plan will also be vetted by one traffic expert so that these drains do not hinder the free flow of traffic. Further, the drainage plan will be checked through joint inspection with the engineers of local bodies/development authority so that the drainage plan is totally integrated with the local body drainage plan. The drain cover should be strong enough to withstand the weight of light commercial vehicle. Any existing drain which will be disturb/ damages during the construction activity shall be restore to its original condition and connections.

The Contractor shall be responsible for the restoration of areas disturbed during construction works any areas disturbed by the construction activity, either inside or outside the Project Right of Way, external areas and Site Areas, shall be reinstated to their original condition, or better, with new materials, including but not necessarily limited to, sidewalks, kerbs, median, railing, road markings, road signage, other road furniture, bus stops, boundary walls, parking lots, access roads, adjacent roads, drains, Street light, Traffic Signal Lights, Junction, adjacent properties and landscaping. Grass cover shall be provided for any bare earth surface areas, along with proper provisions for surface drainage.

## 6.1 Drainage system of Tunnel

Drainage system including surface and subsurface drains for the Project Highway including crossroads shall be provided as per section 5 of the manual. Drain shall conform to the cross- sectional features and other details as given in **Appendix B-III**.

*Note: Size of Channels to be constructed as per Hydrological requirement and as per site requirement.*

## 7. Design of Structures

All structures proposed in the project Tunnel shall be design by the concessionaire and approved by IE as per design requirements. The indicated plan and cross section including General arrangement is attached in Appendix-I & Appendix-II of Schedule-B. except wherever expansion joints have been provided, the pavement layers shall be continued over the structures for smooth riding quality of the project Tunnel. These structures shall be designed considering the dead load of pavement layers.

The overall width of the structures shall be as given as **Appendix-II** of Schedule-B.

## 7.1 Intermodal Hubs at Shaft Location:

All the shaft locations shall be developed as a 5 level intermodal Hubs. However, the foundation design of intermodal hubs building shall be done for 5B + G +15 story industrial/commercial building. All the shaft location will be used for the launching & retrieval of Tunnel Boring Machine, transportation of tunnel construction material and taking out muck/excavated material during the construction phase. After the construction, this location shall be developed as intermodal Hubs. An indicative plan & section is attached in Appendix-I of Schedule-B. The intermodal Hubs will house services such as SCADA, Control Centers, Tunnel ventilations, Lifts, Elevators, boarding & Deboarding of passengers and other control systems of tunnel operation and maintenance as well as charging points of electric buses as mentioned in Schedule C & Schedule D.

The lowest level (1st level) will have platform for deboarding and onboarding on Electrical buses, 2nd level shall be for services related to Tunnel & electric Bus system, 3rd level shall cater to car parking and upper two levels (4th and 5th level) will have commercial spaces.

The Concessionaire shall complete the construction in all respects including firefighting, lighting, air conditioning and also design the control services (ventilation, firefighting etc.) for the operation and maintenance of Project Tunnel including the development of lobby level (ground level) which is the space

for internal & external vehicular movement, land scaping completes in all respects.

The indicative floor plans and the sections and specifications are attached at Appendix B-VI. The Concessionaire shall develop intermodal hubs following all relevant rules & regulations for environment and urban planning.

Advertisement and branding rights: The Concessionaire may auction naming rights for entry/exit ramps and intermodal hubs, as well as monetize advertisement spaces in toll Plazas and Intermodal Hubs for additional revenue, in line with existing and future advertising policies of the Government of Karnataka.

From the Intermodal Hubs:

Parking and retail spaces in the intermodal hubs: Concessionaire may utilize spaces in the intermodal hubs (ensuring layouts in line with DPR) to create parking spaces and retail spaces for additional revenues. The parking fees and minimum area to be devoted to parking shall be as per the guidelines defined by the Authority. With respect to the retail spaces, a maximum FSI of 5 is permitted for development for the Intermodal Hubs above the surface (being Transit Oriented Development), which might change basis the existing rules and laws of the State Government.

The land for these hubs shall be provided to the Concessionaire by the Government. The Intermodal Hubs shall be developed in accordance with Clause 12.8.

The risk for ancillary revenues as well as any additional costs related to the same shall be borne solely by the Concessionaire. While these ancillary revenues will not be included in the calculations for review of the Concession Period, the Concessionaire must make all records of ancillary revenue available for audits as and when directed by the Authority.

**Traffic Control Devices and Road Safety Works**

Traffic control devices and road safety work shall be provided in accordance with IRC 67, IRC:SP:91.

**8. Traffic Signs:**

Traffic signs shall be provided as per IRC 67 as mentioned in Schedule-C

**9. Pavement Marking:**

Pavement markings shall be completed as per IRC 35 as mentioned in Schedule-C

**10. Roadside Furniture**

It shall be provided as mentioned in Schedule C.

**11. Diversion Plans**

The traffic diversion plans shall be prepared as per IRC SP 55 for smooth flow of traffic and safety. During the construction of cut and cover and NATM the diversion plan is to be prepared as per IRC:SP:55-2018. And the provision of traffic decking is to be done as per site specific requirement for smooth flow of traffic during construction.

**12. Interface Management**

The Concessionaire is responsible for coordinating their own design, technical, programming, and construction activities while also ensuring seamless coordination with other Project Contractors, Utility Agencies, Authorities, Service Providers, Developers, Consultants, and Engineers. This is crucial to avoid rework, adhere to project timelines, and achieve a fully integrated construction process.

**Key Responsibilities:**

**General Coordination:**

- Provide necessary design and construction information to Interfacing Contractors in a timely manner.
- Ensure all requirements are communicated before deadlines outlined in the Interface Management Plan (IMP).
- Maintain a clear flow of information through documented correspondence, meeting minutes, and drawings.
- Resolve disputes with Interfacing Contractors proactively; unresolved issues will be decided by the Engineer.

- If an Interfacing Contract is yet to be awarded, coordinate directly with the Engineer until the contractor is appointed.

**Dedicated Coordination Team:**

- Establish a dedicated team led by a Chief Interface Coordinator based in Project Site, reporting to the Project Manager.
- Monitor and adjust the project schedule to avoid delays.
- Identify provisions for equipment and facilities needed by Interfacing Contractors and incorporate them into the design.
- Regularly collect progress data through site inspections, meetings, reports, and turnaround documents.

**Design Interface:**

- Adhere to critical cut-off dates in the IMP to avoid project delays.
- Begin coordination as soon as Interfacing Contracts are awarded.
- Develop design to a level that enables effective interaction with Interfacing Contractors.
- Submit joint confirmation with Interfacing Contractors on design coordination for consistency.
- Ensure continuous information exchange and timely design updates.

**Construction Interface:**

- Maintain coordination from mobilization to project completion.
- Overlap construction and design interface, ensuring provisions for embedded items like pipes, ducts, and cableways.
- Avoid work interference with Interfacing Contractors, ensuring smooth execution.
- Follow Engineer's instructions on work sequencing.
- Indemnify the Employer against costs arising from coordination failures.

## 13. Dumping Sites

Undertake extraction, transport & disposal of muck, soil, earth. No land shall be provided by the Authority for the same. In case government land is available, the same may be made available to the Concessionaire on a lease basis as per guidance value. Additionally, if there are land identified where muck is required by the Authority for levelling purpose, the Concessionaire must dispose the muck at these sites (including levelling) free of cost within the radius of 30 km, from the point of extraction. The Concessionaire will have to present a Muck Disposal Plan according to the applicable rules and regulations of Government of Karnataka and Government of India.

However, the material obtained from tunnel excavation, if suitable, may be used by the Concessionaire for refilling and restoration purposes within the Project Tunnel. The excavated material must not be used by the Concessionaire for commercial purposes.

## 14. Compulsory Afforestation and Replantation

The loss of vegetation due to the construction of tunnel and intermodal hubs is to be taken care of by the Concessionaire as per the relevant laws for the environment & forest. This will include cutting of trees, transplanting trees and maintenance and care of transplanted trees at receptor site for a period of 5 years ensuring that the at least 90 % trees are successfully regenerated. Trees are required to be planted by the concessionaire as compensatory afforestation in accordance with the Karnataka State Guidelines in consultation with the authorities.

The Concessionaire shall survey the land affected by the construction of Project Tunnel for identification of affected trees, taking measurements, preparing plan indicating location, species and girth of the trees on the construction plan and obtain permission of the environment and forest department. No change of scope shall be permitted for the above operations are required to be planted by the concessionaire as compensatory afforestation in accordance with the Karnataka State Guidelines in consultation with the authorities.

## 15. Change of Scope

The length and width of all types of structures and Tunnel stretches specified herein above shall be treated as an minimum requirement. The actual lengths as required on the basis of detailed investigations shall be determined by the Concessionaire in consultation with Independent Engineer and in accordance with the Specifications and Standards. Any variations in the lengths specified in this Schedule-B shall not constitute a Change of Scope.

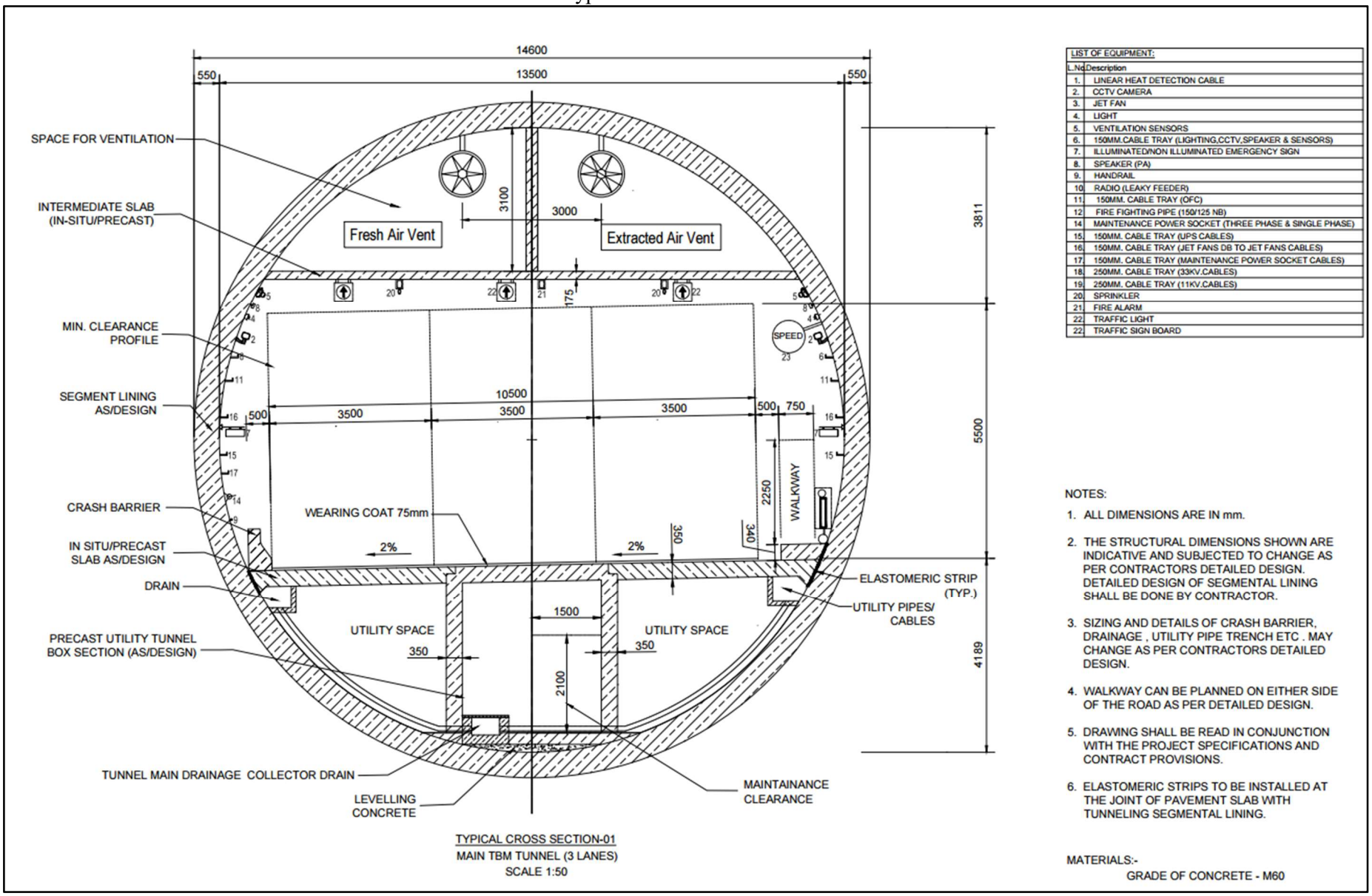
## 16. Protection Measures

The at his cost shall be liable to assess the adequacy of the proposed Protection works for project as given in the Contract Document, by way of carrying out Geo- technical Investigations & detailed design, if he finds that some additional measures for Tunnels/Temporary protection during traffic management /Temporary protection during excavation are required to be undertaken, these shall be pre-assessed and got approved from the Independent Engineer/Authority before execution. No change of scope shall be permitted for the above operation.

***Appendix B-I***

## 1. Typical Cross-sections

Typical Cross Sections are enclosed.



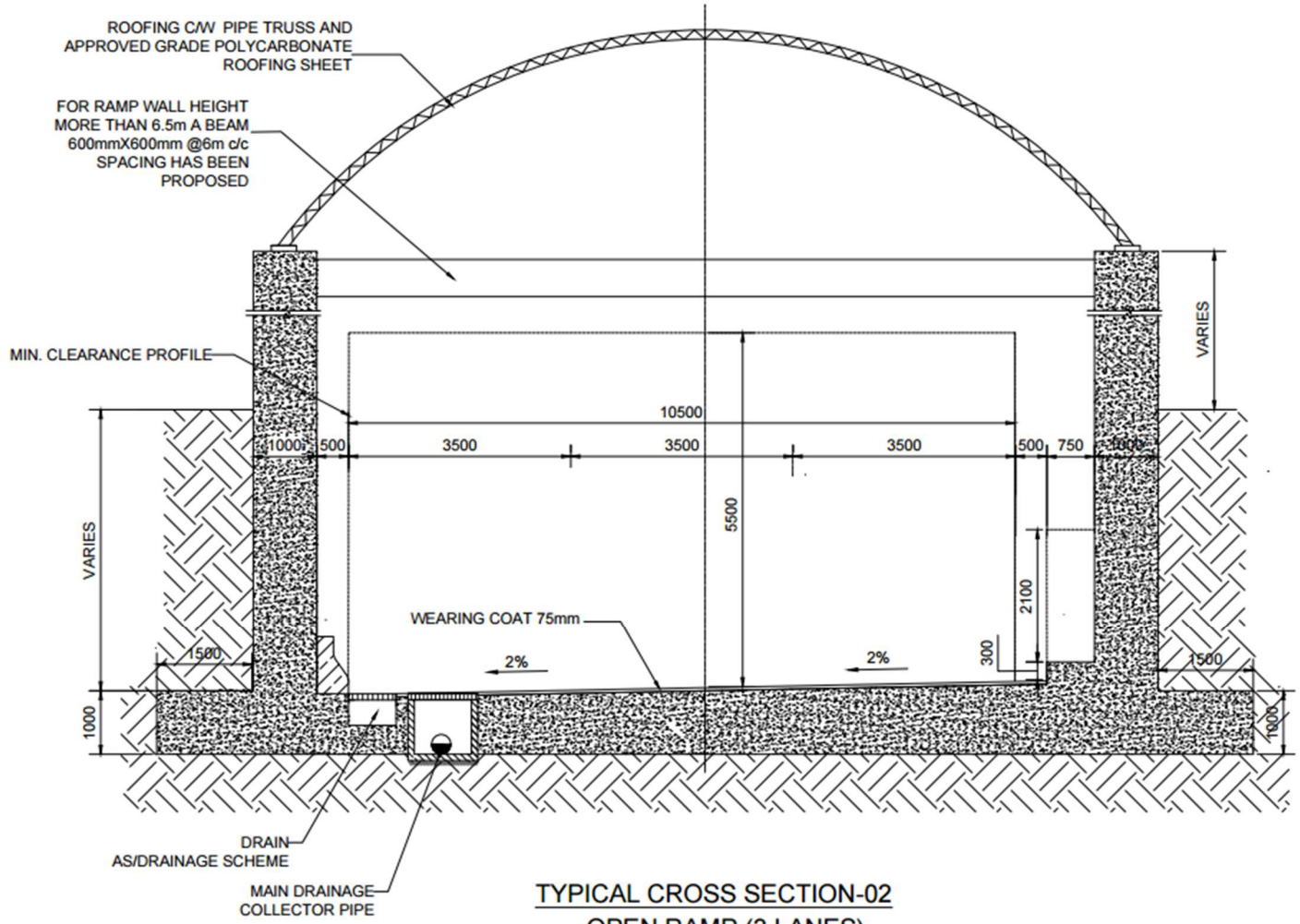

TYPICAL CROSS SECTION-01
MAIN TBM TUNNEL (3 LANES)
SCALE 1:50

| LIST OF EQUIPMENT: | |
|---|---|
| L.No. | Description |
| 1. | LINEAR HEAT DETECTION CABLE |
| 2. | CCTV CAMERA |
| 3. | JET FAN |
| 4. | LIGHT |
| 5. | VENTILATION SENSORS |
| 6. | 150MM.CABLE TRAY (LIGHTING,CCTV,SPEAKER & SENSORS) |
| 7. | ILLUMINATED/NON ILLUMINATED EMERGENCY SIGN |
| 8. | SPEAKER (PA) |
| 9. | HANDRAIL |
| 10 | RADIO (LEAKY FEEDER) |
| 11. | 150MM. CABLE TRAY (OFC) |
| 12. | FIRE FIGHTING PIPE (150/125 NB) |
| 14. | MAINTENANCE POWER SOCKET (THREE PHASE & SINGLE PHASE) |
| 15. | 150MM. CABLE TRAY (UPS CABLES) |
| 16. | 150MM. CABLE TRAY (JET FANS DB TO JET FANS CABLES) |
| 17. | 150MM. CABLE TRAY (MAINTENANCE POWER SOCKET CABLES) |
| 18. | 250MM. CABLE TRAY (33KV.CABLES) |
| 19. | 250MM. CABLE TRAY (11KV.CABLES) |
| 20. | SPRINKLER |
| 21. | FIRE ALARM |
| 22. | TRAFFIC LIGHT |
| 22. | TRAFFIC SIGN BOARD |

NOTES:

1. ALL DIMENSIONS ARE IN mm.
2. THE STRUCTURAL DIMENSIONS SHOWN ARE INDICATIVE AND SUBJECTED TO CHANGE AS PER CONTRACTORS DETAILED DESIGN. DETAILED DESIGN OF SEGMENTAL LINING SHALL BE DONE BY CONTRACTOR.
3. SIZING AND DETAILS OF CRASH BARRIER, DRAINAGE , UTILITY PIPE TRENCH ETC . MAY CHANGE AS PER CONTRACTORS DETAILED DESIGN.
4. WALKWAY CAN BE PLANNED ON EITHER SIDE OF THE ROAD AS PER DETAILED DESIGN.
5. DRAWING SHALL BE READ IN CONJUNCTION WITH THE PROJECT SPECIFICATIONS AND CONTRACT PROVISIONS.
6. ELASTOMERIC STRIPS TO BE INSTALLED AT THE JOINT OF PAVEMENT SLAB WITH TUNNELING SEGMENTAL LINING.

MATERIALS:-
GRADE OF CONCRETE - M60



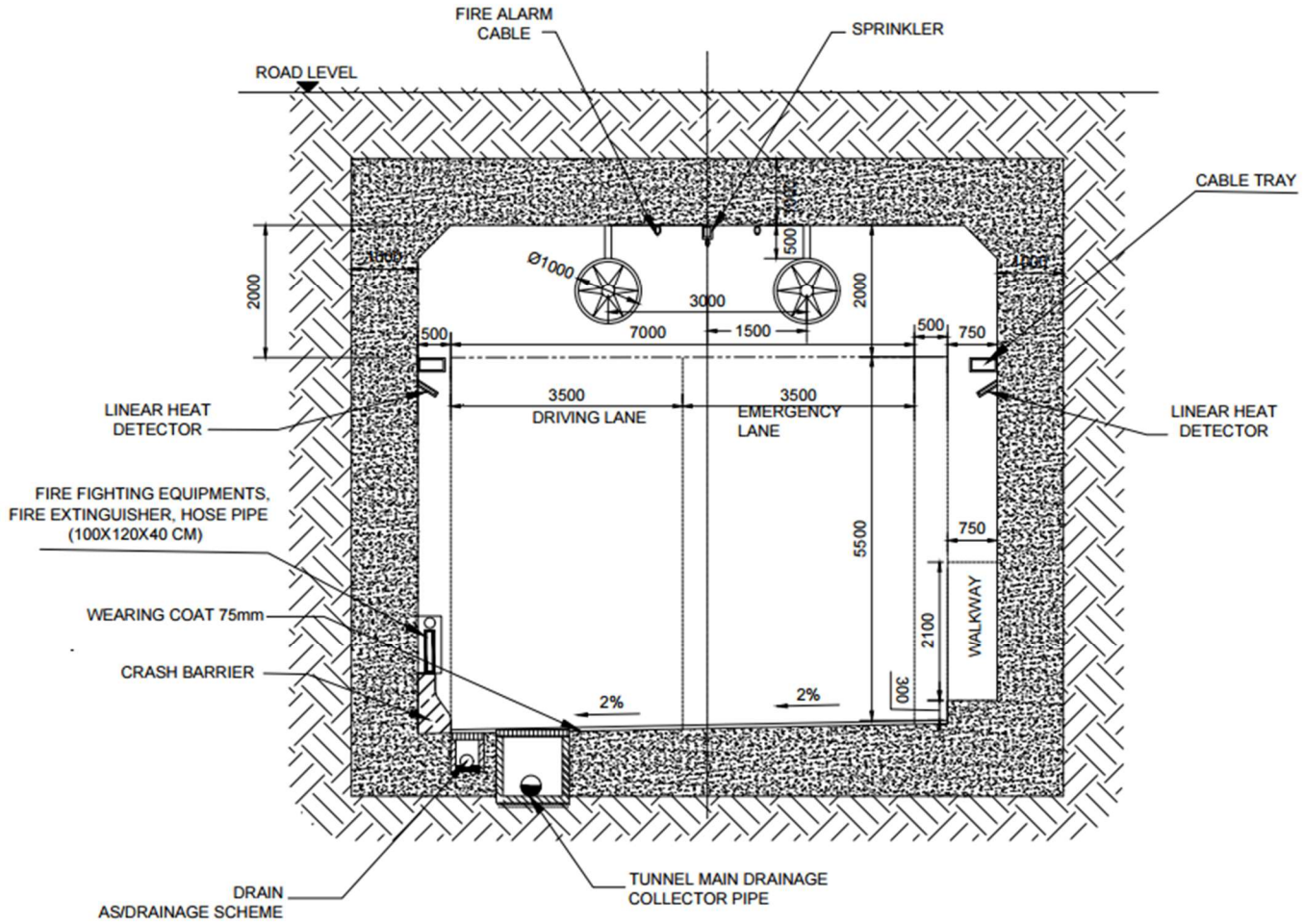

TYPICAL CROSS SECTION-02
OPEN RAMP (3 LANES)
SCALE 1:50

NOTES:

1. ALL DIMENSIONS ARE IN mm.
2. THE STRUCTURAL DIMENSIONS SHOWN ARE INDICATIVE AND SUBJECTED TO CHANGE AS PER CONTRACTORS DETAILED DESIGN.
3. SIZING AND DETAILS OF CRASH BARRIER, DRAINAGE , UTILITY PIPE TRENCH ETC . MAY CHANGE AS PER CONTRACTORS DETAILED DESIGN.
4. WALKWAY CAN BE PLANNED ON EITHER SIDE OF THE ROAD AS PER DETAILED DESIGN.
5. DRAWING SHALL BE READ IN CONJUNCTION WITH THE PROJECT SPECIFICATIONS AND CONTRACT PROVISIONS.

MATERIALS:

GRADE OF CONCRETE - M35
GRADE OF STEEL Fe550D



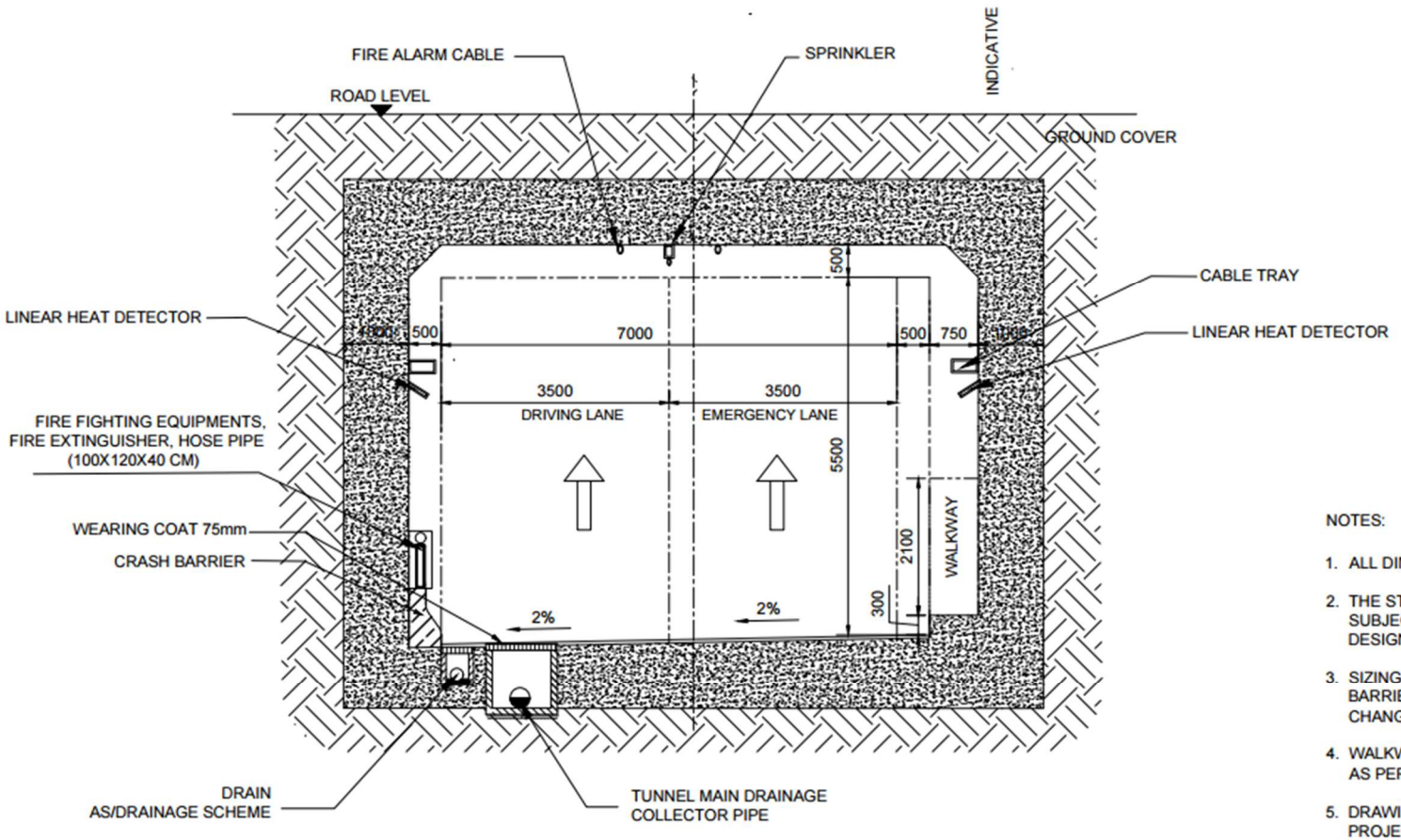

TYPICAL CROSS SECTION-03
CUT AND COVER SECTION FOR ENTRY/EXIT (2 LANE)

SCALE 1:50

NOTES:

1. ALL DIMENSIONS ARE IN mm.
2. THE STRUCTURAL DIMENSIONS SHOWN ARE INDICATIVE AND SUBJECTED TO CHANGE AS PER CONTRACTORS DETAILED DESIGN. DETAILED DESIGN OF LINING SHALL BE DONE BY CONTRACTOR.
3. SIZING AND DETAILS OF CRASH BARRIER, DRAINAGE , UTILITY PIPE TRENCH ETC . MAY CHANGE AS PER CONTRACTORS DETAILED DESIGN.
4. WALKWAY CAN BE PLANNED ON EITHER SIDE OF THE ROAD AS PER DETAILED DESIGN.
5. DRAWING SHALL BE READ IN CONJUNCTION WITH THE PROJECT SPECIFICATIONS AND CONTRACT PROVISIONS.

MATERIALS:
GRADE OF CONCRETE -M35 ,
STEEL GRADE Fe550D



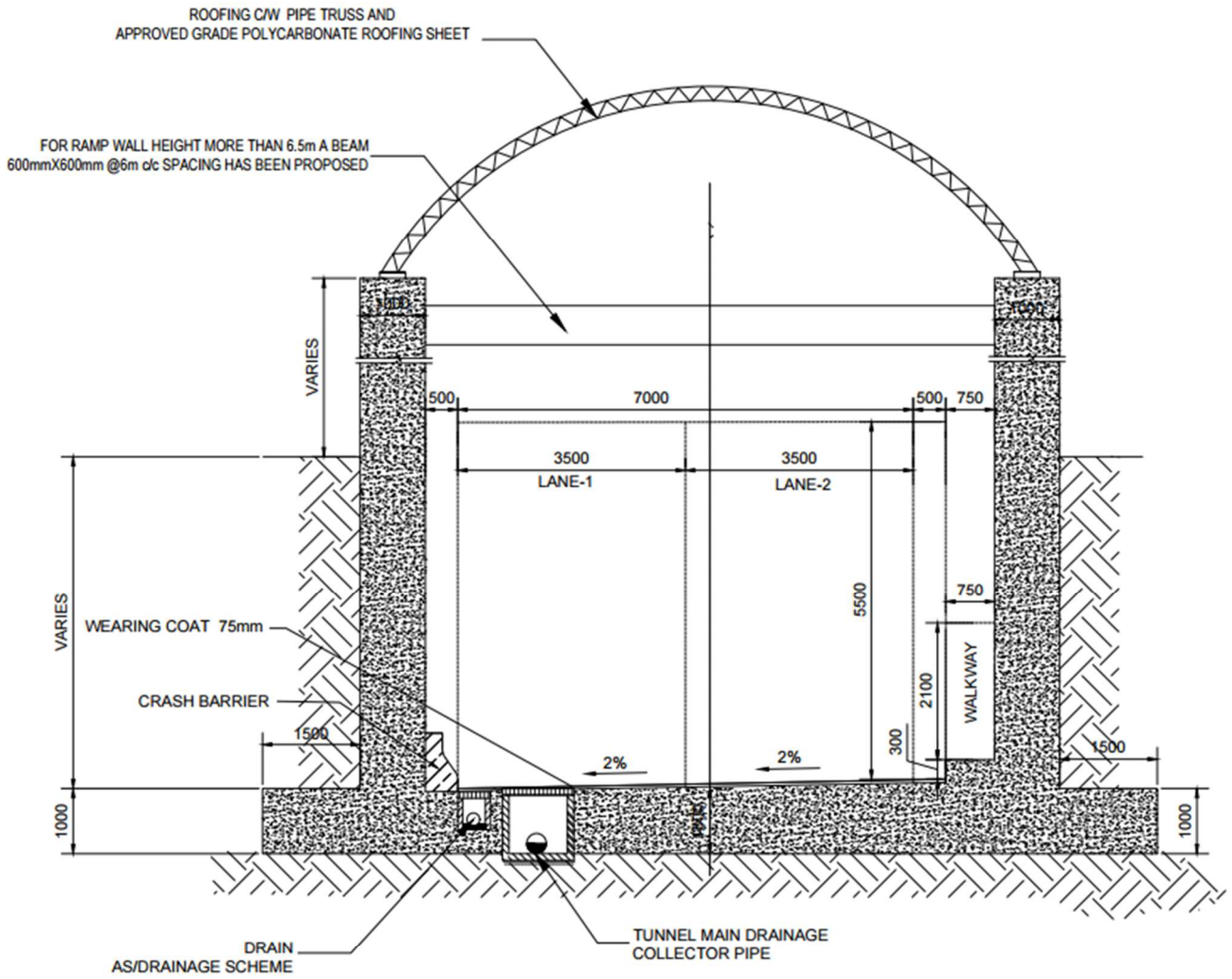

TYPICAL CROSS SECTION-03A
CUT AND COVER TYPICAL SECTION - 2 LANE

REGULAR CROSS SECTION
SCALE 1:50

NOTES:

1. ALL DIMENSIONS ARE IN mm.
2. THE STRUCTURAL DIMENSIONS SHOWN ARE INDICATIVE AND SUBJECTED TO CHANGE AS PER CONTRACTOR'S DETAILED DESIGN.
3. SIZING AND DETAILS OF TYPICAL DETAILS OF CRASH BARRIER , UTILITY PIPE TRENCH , MAIN DRAINAGE ETC. MAY CHANGE AS PER CONTRACTOR'S DETAILED DESIGN.
4. WALKWAY CAN BE PLANNED ON EITHER SIDE OF THE ROAD AS PER DETAILED DESIGN .
5. DRAWINGS SHALL BE READ IN CONJUNCTION WITH THE PROJECT SPECIFICATIONS AND CONTRACT PROVISIONS.
6. CROSS SECTION TO BE READ IN CONJUNCTION WITH TCS-3A.

MATERIALS:
GRADE OF CONCRETE -M35 ,
STEEL GRADE Fe550D

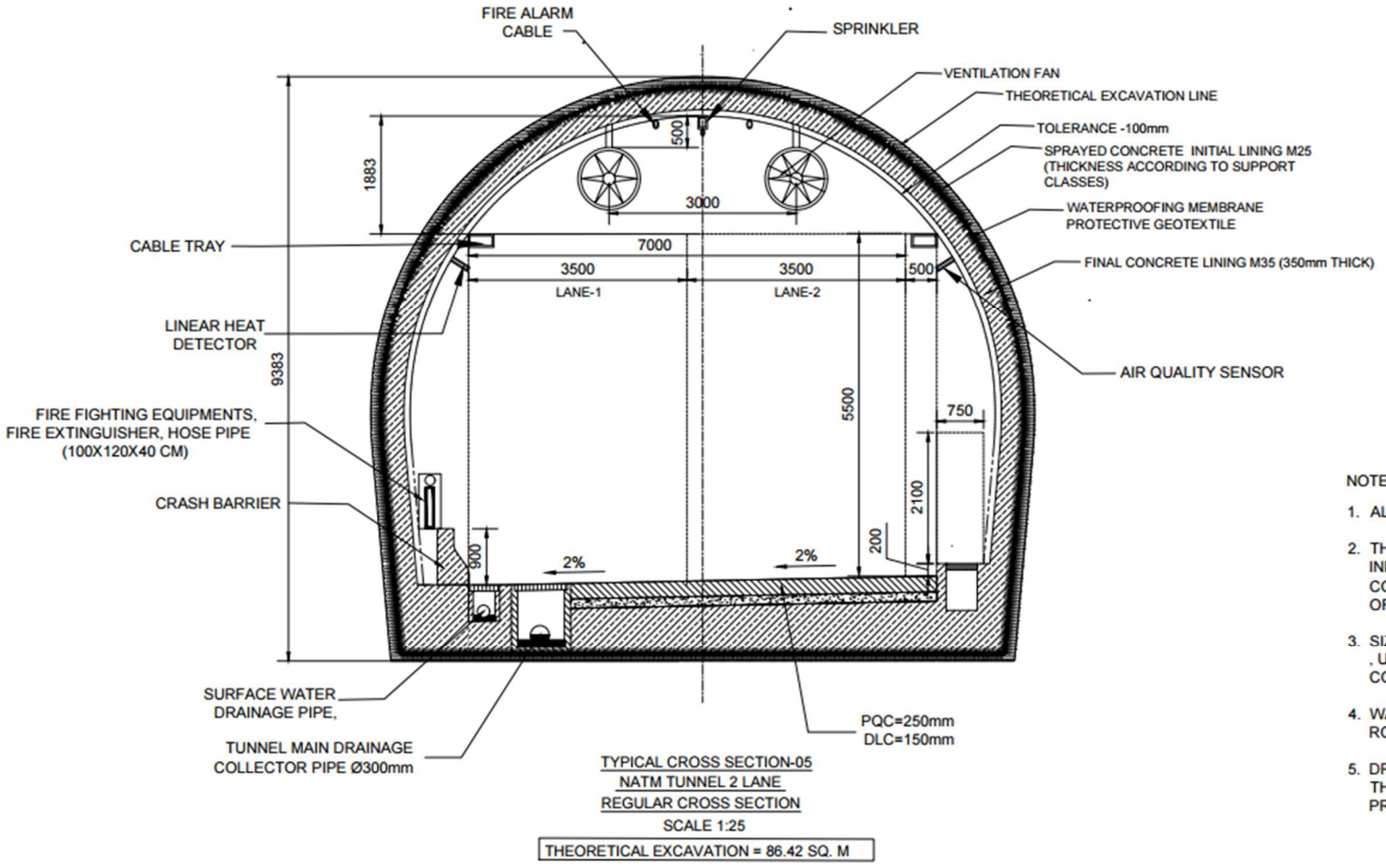



TYPICAL CROSS SECTION-04
OPEN RAMP SECTION FOR ENTRY/EXIT (2 LANE)

SCALE 1:50

NOTES:

1. ALL DIMENSIONS ARE IN mm.
2. THE STRUCTURAL DIMENSIONS SHOWN ARE INDICATIVE AND SUBJECTED TO CHANGE AS PER CONTRACTORS DETAILED DESIGN. DETAILED DESIGN OF LINING SHALL BE DONE BY CONTRACTOR.
3. SIZING AND DETAILS OF CRASH BARRIER, DRAINAGE , UTILITY PIPE TRENCH ETC . MAY CHANGE AS PER CONTRACTORS DETAILED DESIGN.
4. WALKWAY CAN BE PLANNED ON EITHER SIDE OF THE ROAD AS PER DETAILED DESIGN.
5. DRAWING SHALL BE READ IN CONJUNCTION WITH THE PROJECT SPECIFICATIONS AND CONTRACT PROVISIONS.




TYPICAL CROSS SECTION-05
NATM TUNNEL 2 LANE
REGULAR CROSS SECTION
SCALE 1:25

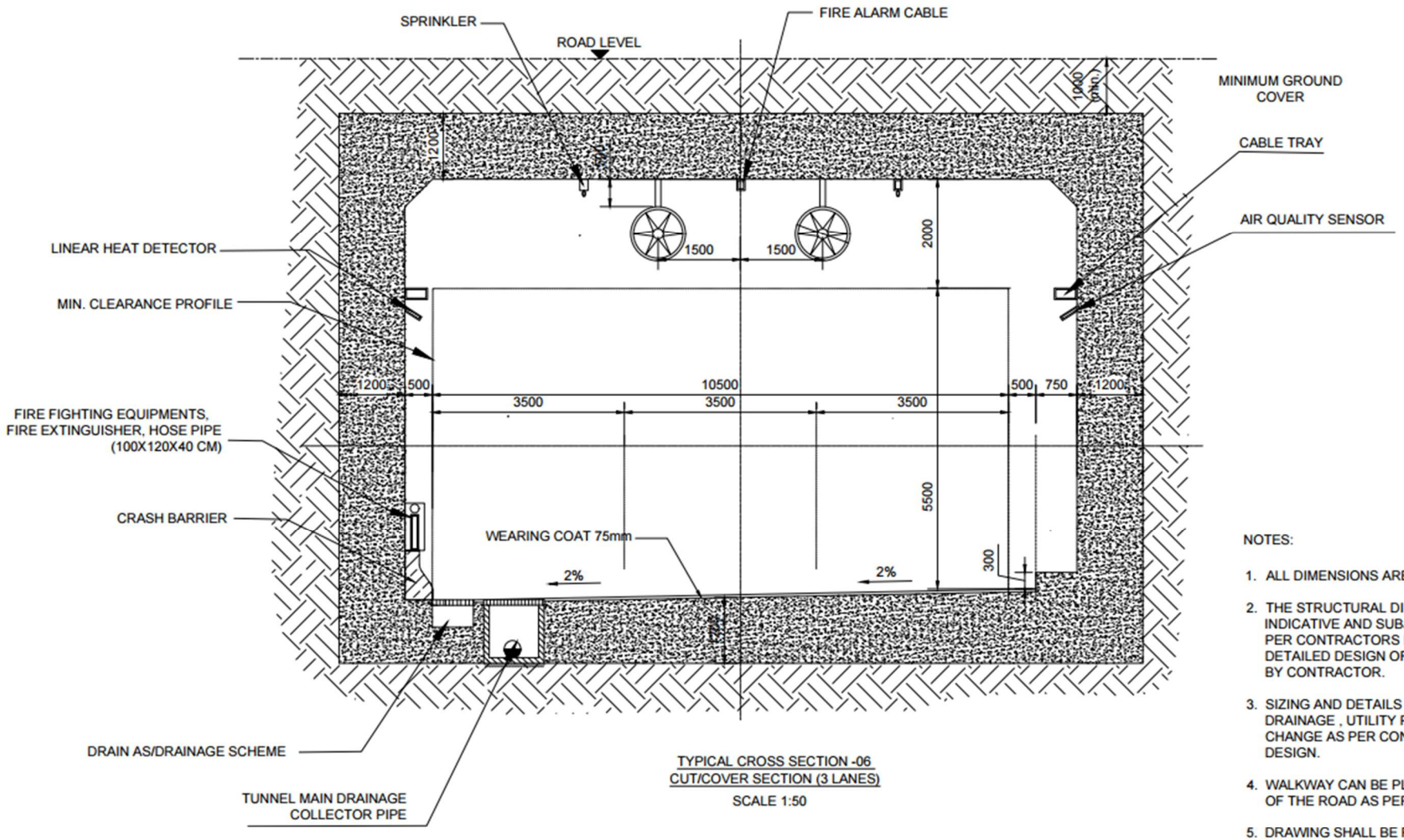
THEORETICAL EXCAVATION = 86.42 SQ. M

NOTES:

1. ALL DIMENSIONS ARE IN mm.
2. THE STRUCTURAL DIMENSIONS SHOWN ARE INDICATIVE AND SUBJECTED TO CHANGE AS PER CONTRACTORS DETAILED DESIGN. DETAILED DESIGN OF LINING SHALL BE DONE BY CONTRACTOR.
3. SIZING AND DETAILS OF CRASH BARRIER, DRAINAGE , UTILITY PIPE TRENCH ETC . MAY CHANGE AS PER CONTRACTORS DETAILED DESIGN.
4. WALKWAY CAN BE PLANNED ON EITHER SIDE OF THE ROAD AS PER DETAILED DESIGN.
5. DRAWING SHALL BE READ IN CONJUNCTION WITH THE PROJECT SPECIFICATIONS AND CONTRACT PROVISIONS.

MATERIALS:

GRADE OF CONCRETE - M35

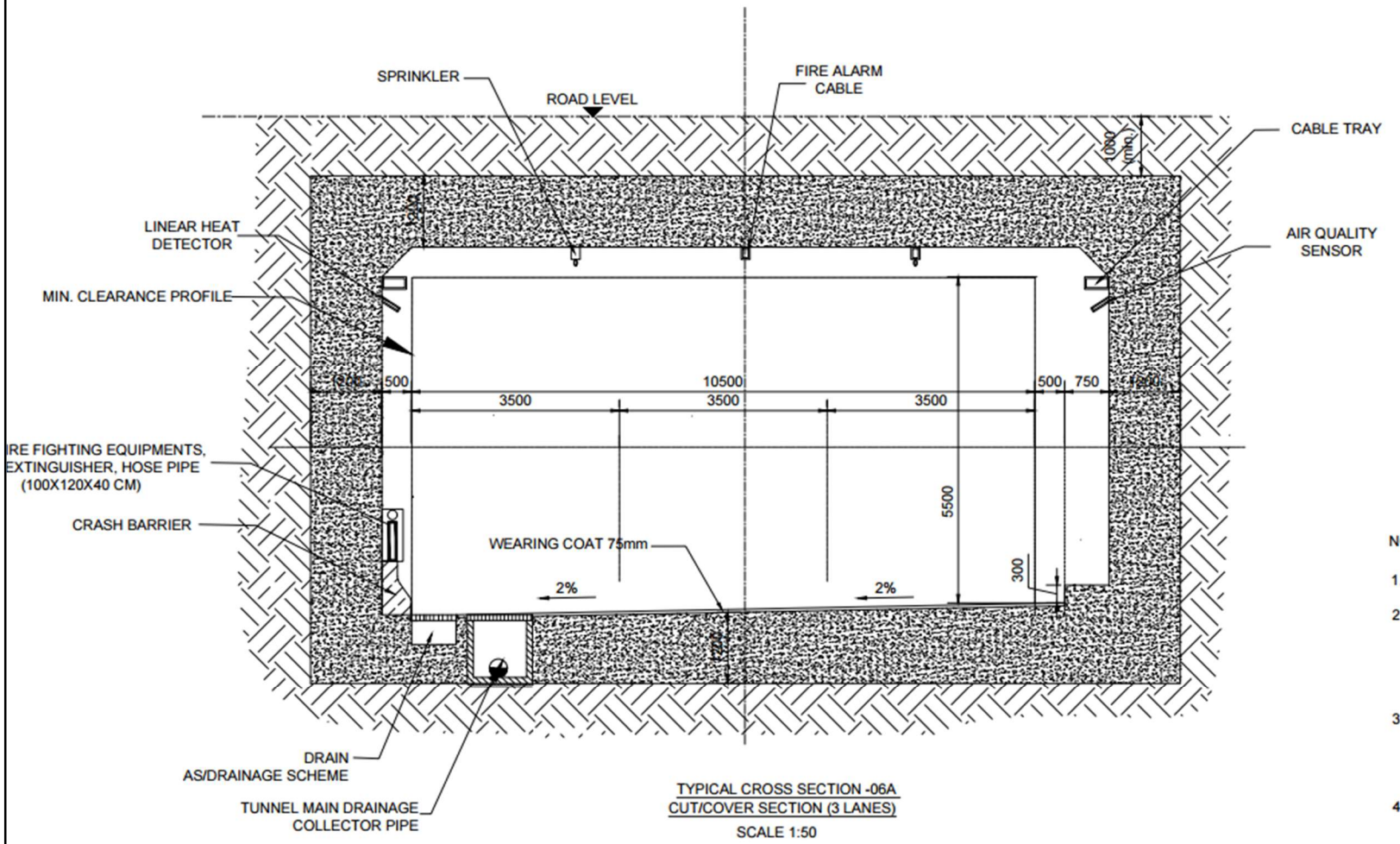



TYPICAL CROSS SECTION -06
CUT/COVER SECTION (3 LANES)
SCALE 1:50

NOTES:

1. ALL DIMENSIONS ARE IN mm.
2. THE STRUCTURAL DIMENSIONS SHOWN ARE INDICATIVE AND SUBJECTED TO CHANGE AS PER CONTRACTORS DETAILED DESIGN. DETAILED DESIGN OF LINING SHALL BE DONE BY CONTRACTOR.
3. SIZING AND DETAILS OF CRASH BARRIER, DRAINAGE , UTILITY PIPE TRENCH ETC . MAY CHANGE AS PER CONTRACTORS DETAILED DESIGN.
4. WALKWAY CAN BE PLANNED ON EITHER SIDE OF THE ROAD AS PER DETAILED DESIGN.
5. DRAWING SHALL BE READ IN CONJUNCTION WITH THE PROJECT SPECIFICATIONS AND CONTRACT PROVISIONS.

MATERIALS
GRADE OF CONCRETE - M35
GRADE OF STEEL Fe550D



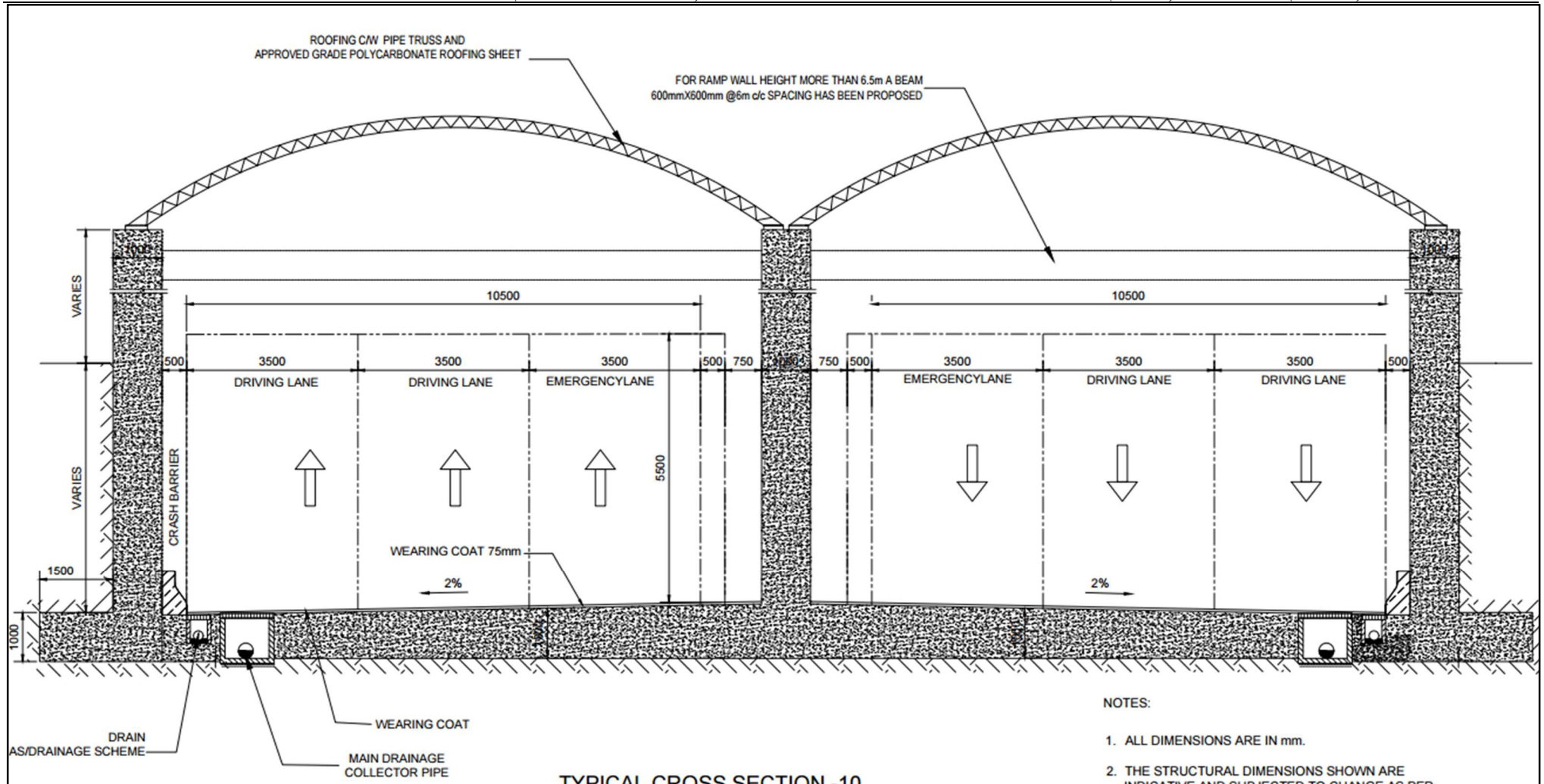

TYPICAL CROSS SECTION -06A
CUT/COVER SECTION (3 LANES)
SCALE 1:50

NOTES:

1. ALL DIMENSIONS ARE IN mm.
2. THE STRUCTURAL DIMENSIONS SHOWN ARE INDICATIVE AND SUBJECTED TO CHANGE AS PER CONTRACTORS DETAILED DESIGN. DETAILED DESIGN OF LINING SHALL BE DONE BY CONTRACTOR.
3. SIZING AND DETAILS OF CRASH BARRIER, DRAINAGE , UTILITY PIPE TRENCH ETC . MAY CHANGE AS PER CONTRACTORS DETAILED DESIGN.
4. WALKWAY CAN BE PLANNED ON EITHER SIDE OF THE ROAD AS PER DETAILED DESIGN.
5. DRAWING SHALL BE READ IN CONJUNCTION WITH THE PROJECT SPECIFICATIONS AND CONTRACT PROVISIONS.

MATERIALS

GRADE OF CONCRETE - M35
GRADE OF STEEL Fe550D

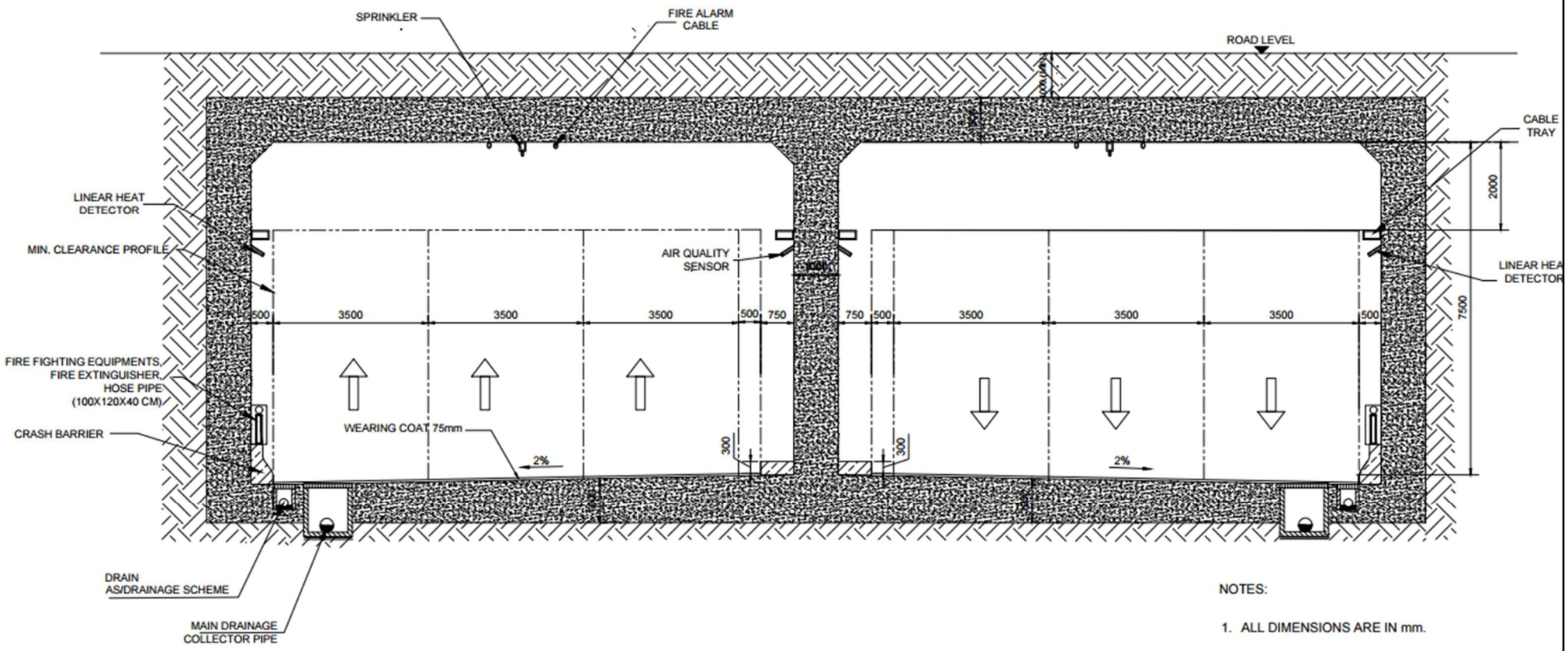



## TYPICAL CROSS SECTION -10
## OPEN RAMP SECTION
## 3LANE+MEDIAN WALL+3LANE
SCALE 1:50

MATERIALS: -
GRADE OF CONCRETE -M35 , STEEL GRADE Fe550D

NOTES:

1. ALL DIMENSIONS ARE IN mm.
2. THE STRUCTURAL DIMENSIONS SHOWN ARE INDICATIVE AND SUBJECTED TO CHANGE AS PER CONTRACTOR'S DETAILED DESIGN.
3. SIZING AND DETAILS OF TYPICAL DETAILS OF CRASH BARRIER , UTILITY PIPE TRENCH , MAIN DRAINAGE ETC. MAY CHANGE AS PER CONTRACTOR'S DETAILED DESIGN.
4. WALKWAY CAN BE PLANNED ON EITHER SIDE OF THE ROAD AS PER DETAILED DESIGN .
5. DRAWINGS SHALL BE READ IN CONJUNCTION WITH THE PROJECT SPECIFICATIONS AND CONTRACT PROVISIONS.




TYPICAL CROSS SECTION-14
CUT AND COVER (3 LANE+MEDIAN WALL+ 3 LANE)
SCALE 1:50

MATERIALS: -

GRADE OF CONCRETE -M35 ,
STEEL GRADE Fe550D

NOTES:

1. ALL DIMENSIONS ARE IN mm.
2. THE STRUCTURAL DIMENSIONS SHOWN ARE INDICATIVE AND SUBJECTED TO CHANGE AS PER CONTRACTOR'S DETAILED DESIGN.
3. SIZING AND DETAILS OF TYPICAL DETAILS OF CRASH BARRIER , UTILITY PIPE TRENCH , MAIN DRAINAGE ETC. MAY CHANGE AS PER CONTRACTOR'S DETAILED DESIGN.
4. WALKWAY CAN BE PLANNED ON EITHER SIDE OF THE ROAD AS PER DETAILED DESIGN .
5. DRAWINGS SHALL BE READ IN CONJUNCTION WITH THE PROJECT SPECIFICATIONS AND CONTRACT PROVISIONS.

***Appendix B-II***

**Alignment Plan**

Alignment Plan and profile is enclosed as Appendix-B-II ( Schedule-B ) in Tender Drawing Volume.

***Appendix B-III***

**Drainage Plan**

The drainage plan as given in Annexure III of Schedule A shall be provided in accordance with the manual.. The indicated Drainage Scheme is Appendix-B-III ( Schedule-B ) in Tender Drawing Volume.

**Appendix B-IV**

## Ventilation, Electrical and Mechanical

Ventilation, Electrical and Mechanical is enclosed as Appendix-B-IV ( Schedule-B ) in Tender Drawing Volume.

**Appendix B-V**

## Traffic Signage Plan

Traffic Signage Plan is enclosed as Appendix-B-V ( Schedule-B ) in Tender Drawing Volume.

**Appendix B-VI**

## SHAFT TYPICAL SECTION

Typical Section of shaft is enclosed as Appendix-B-VI ( Schedule-B ) in Tender Drawing Volume.

# SCHEDULE - C

## *SCHEDULE –C*

### *(See Clause 2.1)*

### *PROJECT FACILITIES*

**1. Project Facilities**

The Concessionaire shall construct the project facilities in accordance with the provisions of this agreement. Such Project facilities shall include:

a) Global Positioning System (GPS) / Global Navigation Satellite System (GNSS)-Based Tolling

b) Roadside furniture

i) Kilometer and Hectometer Board

ii) Traffic Signs

iii) Overhead Signs

iv) Road Marking

v) Road Delineators

vi) Reflective Pavement Markers & Studs

vii) Traffic Impact Attenuators

viii) Boundary wall and Fencing

ix) Variable Message Sign

c) Supervisory Control and Data Acquisition (SCADA) System Interfacing

d) Wayside Amenities / Service Areas

e) Lighting / illumination

f) Bus Bays at Multimodal hubs

g) Environmental Management Plan

h) Land Scaping and Tree Plantation

i) Electrical Buses, Fare collection system, operation & maintenance of fleet & Charging Stations

j) Emergency medical services

k) Crane Service

l) Authority & Independent Engineer's Off ices

m) Digital Tools for Project Monitoring

n) Interfacing Agencies and Management

o) Traffic Management System

p) Logo on precast segments

q) Art / Murals Work

**1.1** Project Facilities to be completed on or before project completion date have been described in Annexure-I of this Schedule-C.

## *Annexure – I*

## *(Schedule-C)*

## *PROJECT FACILITIES*

### 1. Project Facilities

The Concessionaire shall construct the project facilities in accordance with the provisions of this agreement. Such Project facilities shall include:

The Concessionaire shall construct the project facilities in accordance with the provisions of this agreement. Such Project facilities shall include:

a) Global Positioning System (GPS) / Global Navigation Satellite System (GNSS)-Based Tolling

b) Roadside furniture

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e) Lighting / illumination

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g) Environmental Management Plan

h) Land Scaping and Tree Plantation

i) Electrical Buses, Fare collection system, operation & maintenance of fleet & Charging Stations

j) Emergency medical services

k) Crane Service

l) Authority & Independent Engineer's Offices

m) Digital Tools for Project Monitoring

n) Interfacing Agencies and Management

o) Traffic Management System

p) Logo on precast segments

q) Art / Murals Work

**Description of Project Facilities**

Each of the Project Facilities is briefly described below:

**2.Global Positioning System (GPS) / Global Navigation Satellite System (GNSS)-Based Tolling**

The concessionaire shall be responsible for providing necessary interfaces for tolling systems that shall be set up by the Authority or its Concessionaires.

1 As part of the Intelligent Tolling Infrastructure under this BOOT Project, the Concessionaire shall deploy a state-of-the-art GNSS (Global Navigation Satellite System) and ANPR (Automatic Number Plate Recognition)

based tolling solution. This dual-layered system is designed to facilitate accurate, contactless, and efficient toll collection across all lanes at the entry and exit points of the main tunnel as well as at intermediate ramps.

2 The GNSS-based tolling system will enable satellite-guided, distance-based toll calculation. Each vehicle participating in the tolling network shall be equipped with an On-Board Unit (OBU), capable of tracking movement through multi-constellation GNSS (including GPS, GLONASS, Galileo, and IRNSS/NavIC). These OBUs will offer high positional accuracy (within ±2.5 meters) and shall communicate toll data in real-time via GSM, GPRS, or 4G/5G LTE networks. Additionally, the OBUs will be designed for low power consumption, possess anti-tampering features, and support Over-the-Air (OTA) firmware upgrades. The data architecture shall include geo-fencing capabilities and encrypted communication protocols (TLS 1.2 or higher) to ensure secure and efficient tolling operations.

3 Complementing the GNSS system, ANPR cameras will be installed at all entry and exit lanes of the tunnel and ramps. These high-resolution, infrared-enabled cameras will ensure accurate vehicle identification both during day and night conditions. Designed to withstand harsh weather, the cameras will be housed in IP66 and IK10-rated enclosures, with varifocal lenses to capture license plates across diverse vehicle types and angles. The system will be capable of recognizing Indian vehicle registration formats with ≥95% accuracy in daylight and ≥90% in low-light environments. The captured data, including license plate images, vehicle snapshots, time stamps, and location identifiers, will be transmitted securely to the central Toll Management System and integrated with government vehicle databases (e.g., VAHAN).

4 The system infrastructure will be supported by a robust communication network, consisting of a high-speed optical fiber backbone and a redundant wireless layer (4G/5G with encrypted VPN or IPSec protocols). System latency shall be maintained under 150 milliseconds to support real-time data transmission and toll computation.

5 To ensure uninterrupted operation, the entire system shall be equipped with redundant power supplies, including UPS and generator backups capable of sustaining at least 8 hours of autonomous function. Self-diagnostic and auto-recovery features will be built into both GNSS and ANPR systems to maintain a minimum 99.5% uptime.

6 All equipment and software deployed will conform to relevant national and international standards, including EMI/EMC compliance (such as EN 55032/55024), operating temperature ranges of -10°C to +60°C, and humidity resistance up to 95% (non-condensing). Cybersecurity measures such as AES-256 encryption, access control protocols, and complete audit trails will be integral to the system design, ensuring compliance with India's data protection regulations.

7 Furthermore, a centralized monitoring dashboard will provide real-time oversight, performance metrics, and diagnostic alerts. Monthly performance reports will include system uptime statistics, ANPR recognition accuracy, toll collection summaries, and exception logs.

8 The integrated GNSS and ANPR-based tolling solution proposed for this tunnel project will deliver a secure, scalable, and future-ready tolling ecosystem aligned with modern ITS standards and regulatory requirements in India.

9 The Tolling system shall have interface with the tolling system of adjacent tunnel of other packages.

**b) Roadside Furniture**

The Road Furniture details provided in the Employer's Drawings are indicative. The road, Traffic and Safety sign, marking drawings provided therein are for reference purposes and the Concessionaire shall design the sign and markings as per IRC 67, IRC 35, IRC: SP:85 and another relevant IRC and MoRT&H specification and get the same noticed by the Engineer.

**c) Supervisory Control and Data Acquisition (SCADA) System Interfacing**

The Concessionaire shall supply, test and commission the SCADA (Supervisory Control and Data Acquisition) system in this tunnel which will enable efficient monitoring and controls for various aspects of the tunnel's operations by interfacing with the E&M works that includes ventilation, lighting, traffic management, fire detection, and emergency systems, allowing operators to remotely manage the tunnel's functionality and respond to potential issues in real-time from a central control room located at shaft location. For detailed specifications refer **Schedule D**.

**d) Wayside Amenities / Service Areas**

Wayside Amenities should be provided at Intermodal Hub locations

**e)Lighting / Illumination**

Illumination for overground sections shall be integrated with TICS (Tunnel Integrated Control System). The Tunnel Integrated Control System (TICS) shall serve as the centralized command and coordination platform for the entire tunnel infrastructur. Designed with a focus on safety, reliability, and automation, the TICS will enable real-time monitoring and intelligent control of all electro-mechanical, traffic, and safety systems within the tunnel and associated approach roads.

The TICS will integrate all critical subsystems including tunnel lighting (both normal and emergency), ventilation (jet fans and Saccardo systems), fire detection and suppression, CCTV surveillance with video analytics, public address and emergency call systems, variable message signs (VMS), lane control signals (LCS), environmental monitoring sensors (CO, NOx, visibility, temperature), power supply systems (HT/LT panels, UPS, DG sets), and automatic incident detection (AID). In addition, lighting for overground sections will be seamlessly integrated with TICS for unified operation and control.

The system shall be based on a distributed control architecture with a centralized SCADA (Supervisory Control and Data Acquisition) platform hosted in the Tunnel Control Room. The communication network will comprise a fiber-optic gigabit Ethernet backbone configured in a redundant ring topology, ensuring high availability and fault tolerance. All field devices shall interface via industrial-grade Programmable Logic Controllers (PLCs) or Remote Terminal Units (RTUs), allowing for reliable and scalable integration.

The SCADA software shall be modular, web-enabled, and based on an open architecture, capable of supporting real-time status displays, alarm management, system diagnostics, and event logging. Operators will interact through a graphical dashboard offering intuitive controls and visual representations of tunnel systems. Alarm management will include prioritized, color-coded alerts with real-time acknowledgments and logging. All system events will be timestamped and stored with a minimum archival capacity of one year. Access to the system shall be role-based, ensuring secure and controlled user permissions for operators, engineers, and administrators.

TICS will support standard communication protocols including Modbus TCP/IP, OPC UA, IEC 61850, SNMP, and ONVIF (for CCTV integration). It shall include strong cybersecurity features such as AES-256 encryption, firewall protection, intrusion detection, and full audit trails to ensure compliance with India’s data security regulations.

The system shall be engineered for high reliability, with a minimum availability of 99.95%. Redundancy shall be provided at multiple levels, including dual SCADA servers in hot-standby mode, dual LAN paths, and dual power supplies. Backup power shall be ensured through UPS (with a minimum 30-minute backup capacity) and diesel generator sets capable of supporting 100% operational load.

Environmental resilience will be achieved through equipment design and placement. Control room components will conform to IP41 protection standards, while field equipment will meet IP65 ratings. The system will function across a temperature range of -10°C to +60°C and comply with EMI/EMC standards such as EN 61000.

To enable broader coordination, TICS shall be capable of integration with external platforms such as State/National Traffic Management Centers, Intelligent Transport Systems (ITS), and GPS/GNSS-based tolling systems.

In addition to automation and monitoring, the system shall support predictive maintenance by tracking equipment usage and performance trends, issuing early warnings for potential failures. Remote diagnostics and firmware upgrades will be enabled for field controllers to reduce downtime and manual interventions.

The Concessionaire shall also provide complete documentation including system architecture, operational manuals, and maintenance procedures, along with comprehensive training to designated operating staff. Training will cover SCADA operations, incident handling, and safety protocols.

In summary, the Tunnel Integrated Control System (TICS) shall serve as the intelligent nerve center of the tunnel infrastructure, offering a secure, automated, and scalable control environment aligned with modern ITS practices and national operational standards

**f) Bus Bays**

Bus Bays should be provided at Intermodal Hub locations.

**g) Environmental Management Plan**

The Concessionaire shall comply with the Environment Management Plan (EMP) including implementation and monitoring of mitigation measures suggested for the protection of environment during the construction and operation phase of the project.

**h) Land Scaping and Tree Plantation**

Land Scaping and Tree Plantation should be provided at Intermodal Hub locations at podium level and locations authorized by the Authority / Independent Engineer.

**i) Electrical Buses, Fare collection system, operation & maintenance of fleet & Charging Stations**

**Neo-Bus / High-Speed Articulated Bus System (12–18 meters)**

The Neo-Bus system is envisioned as a modern, high-capacity urban transit solution specifically tailored to the Bengaluru urban environment. This system is designed to address the needs of dense metropolitan city by offering seamless integration into smart transport infrastructure while adhering to Indian regulations and climate conditions. The bus system shall be operated and maintained by the Concessionaire with a fleet of a minimum of 10 buses. The bus system shall be integrated with the bus system of other packages of tunnel as well as the overall urban transport system of Bengaluru with the approval of the Authority.

Tolls from buses: The Concessionaire may collect tolls from buses in addition to tolls from passenger vehicles, in accordance with the toll rates as per Article 27.

**1. Vehicle Technical Specifications (OEM Scope)**

**1.1 General Configuration**

The Neo-Bus is a high-capacity urban transit vehicle ranging from 12 to 18 meters in length. These buses are configured for efficient intra-city transit with a standard width of 2.5 meters (±50 mm) and a height between 3.4 to 3.8 meters (including rooftop battery packs and HVAC systems). The floor height is maintained at ≤400 mm for compatibility with Indian BRT platforms. Passenger capacity standards are minimum 85 passengers for 12-meter and 135–150 passengers for 18-meter articulated versions.

**1.2 Body & Chassis**

Buses feature corrosion-resistant stainless steel or mild steel body structures with aluminum or FRP panels. Flooring must be anti-skid, 3 mm thick vinyl with fire-retardant properties conforming to Indian safety standards. The chassis may be ladder-type or monocoque based on OEM designs from Indian manufacturers such as Tata Marcopolo, Ashok Leyland, Eicher, JBM, and Olectra.

**1.3 Propulsion System**

In line with national sustainability goals, buses shall be 100% electric and must deliver a minimum continuous power of 150 kW and a peak of 250 kW. Max operational speed is capped at 80 km/h.

**1.4 Battery System (For EVs)**

Battery chemistry may include LFP or NMC, certified as per AIS-156 and BIS. Capacities must be ≥ 200 kWh (12m) and ≥ 300 kWh (18m) with a city range of 180–250 km per charge. Charging must use CCS2 plug-in systems and optionally support pantographs. Indian manufacturers like Exide, Amara Raja, and Nexcharge are preferred battery suppliers.

### 1.5 Suspension, Braking & Safety

Vehicles must feature ECAS suspension systems to manage road gradients. Braking systems must be full-air dual-circuit with ABS and EBS. Power steering with ≤12.5 m turning radius is mandatory. Fire suppression systems compliant with IS 14609 must be installed in engine and battery compartments. Emergency exits and panic buttons are also required.

## 2. Passenger Amenities & Interior Fitments

### 2.1 Doors & Accessibility

Three pneumatically operated doors are required per bus: two double leaf for passengers and one emergency door. Entry/exit must be compatible with 300–350 mm high BRT platforms common in Indian cities.

### 2.2 Interior Features

Seating must be vandal-resistant, ergonomic, and made from FRP or injection-molded material. Air conditioning systems with ≥36 kW capacity should be capable of handling peak summer conditions. Interior lighting must be LED-based and PIS must support Hindi, Kannada and English audio-visual announcements.

### 2.3 Surveillance & ITS

Each bus will feature a minimum of four CCTV cameras connected to onboard storage and real-time backend systems. Passenger counting sensors, vehicle diagnostics, GPS, and Wi-Fi hotspots are mandatory. ITS integration must meet MoRTH and AIS-140 compliance.

## 3. Bus Station Infrastructure

### 3.1 Platform Requirements

Platforms must be ≥20 meters long and ≥3 meters wide, with 300–350 mm height. Shelters must include stainless steel or aluminum roofing with weather-resistant polycarbonate. Public amenities should include tactile flooring, ticket validators, CCTV, and seating.

## 4. Depot & Maintenance Infrastructure

### 4.1 Depot Design

Depots must support a minimum of 10 buses with facilities like EV charging stations, battery storage rooms, washing bays, and repair pits. Power infrastructure must include HT connection and transformers with minimum 1 MW load capacity. Coordination with OEMs is essential.

## 5. Compliance & Certification (Indian Standards)

All vehicles must adhere to CMVR and AIS guidelines:

- AIS-052 (bus body), AIS-140 (ITS), AIS-153 (electric bus)
- Fire Safety: IS 14609 & NBC India 2016
- Battery: AIS-156, IP67, BIS certification
- Electronics: AIS-140 compliance with Command & Control Center integration

## 6. Performance Requirements

| Parameter | Requirement |
|---|---|
| Vehicle Availability | ≥ 95% during peak |

| | |
|---|---|
| Breakdown Rate | ≤ 5 / 10,000 km |
| Maintenance | As per OEM manual |
| Battery Life | ≥ 5 years or 2000 cycles |
| Warranty Support | Minimum 3 years |
| ITS Reporting | Real-time end-to-end system |

**7. Charging Infrastructure (India-Based Vendors)**

DC fast charging must be available using 180–240 kW CCS2 chargers with ≤90-minute charging times. AC chargers (60–80 kW) must provide full charge in 4–6 hours. Power infra must support HT connections. Approved vendors include Tata Power, Exicom, ABB India, Delta, and Siemens India.

**8. Indian Manufacturer Standards**

All OEMs must provide the following certifications:

- CMVR/AIS-140/153/052
- Battery: AIS-156, BIS license
- Structural: AIS-031 (rollover), AIS-068
- Fire: IS 14609, NBC 2016
- IP Ratings: Battery – IP67; Electronics – IP65
- FAME-II or State EV Policy registration required

**9. Fare Collection System**

The fare collection system for the Neo-Bus / High-Speed Articulated Bus System must be designed to meet the evolving needs of **urban public transport authorities**, **Digital India objectives**, and **National Common Mobility Card (NCMC)** guidelines. The system must be robust, contactless, and scalable for high-frequency intra-city operations, ensuring transparent revenue management, real-time transaction monitoring, and full passenger convenience.

**9.1 System Design & Functionality**

Each Neo-Bus deployed shall be equipped with an **Automatic Fare Collection System (AFCS)** that supports:

a) NCMC-compliant contactless smart cards (RuPay-based)

b) Unified Payments Interface (UPI)-based QR code payments

c) Mobile ticketing via transit apps / SMS-based ticket codes

d) Optional: Onboard ETIMs (Electronic Ticket Issuing Machines) for physical ticketing, operated by conductor (where applicable)

All fare media must work in both online and offline modes to accommodate variable network conditions prevalent in Indian cities.

**9.2 Validator & Device Specifications**

Each bus must have a minimum of 2 to 3 smart fare validators positioned at entry/exit doors with the following features:

a) NCMC-compliant card readers supporting RuPay specifications by NPCI

b) QR code scanners capable of reading Bharat QR / dynamic QR

c) RFID/NFC support (ISO/IEC 14443 Type A/B)

d) Real-time fare deduction, visual/audio confirmation, and multilingual display (Hindi/English/Regional)

e) Rugged design for Indian weather, including anti-vibration, IP54 or better ingress protection

**9.3 Backend Integration**

Validators must communicate with an onboard AFC Controller linked to the Central Fare Clearing House (CFCH) hosted by the State/Central Transport Authority. The backend must:

a) Comply with MoHUA / NCMC AFC architecture

b) Be capable of real-time synchronization over 4G/5G or Depot Wi-Fi

c) Support data analytics dashboards for revenue, ridership, and device performance

d) Be interfaced with the ITS system via AIS-140-compliant architecture

**9.4 Standards & Indian Compliance**

a) NCMC Compatibility: As per NPCI specifications (RuPay / NCMC)

b) PCI-DSS: Compliance for secure payment handling

c) ISO/IEC 14443 & ISO/IEC 18092: Contactless media standards

d) UIDAI Guidelines: If Aadhaar-enabled ticketing is used

e) Bureau of Indian Standards (BIS): Certification for all electronic components where applicable

**9.5 Security & Monitoring**

a) Fare devices must use end-to-end AES encryption

b) Tamper detection sensors, event logging, and remote locking

c) Local storage backup for at least 48 hours of offline transactions

d) Data protection in line with India's Digital Personal Data Protection Act (DPDP), 2023

**9.6 Passenger Interface**

a) Devices must support Hindi, English, Kannada language

b) Audio and visual prompts for fare confirmation and errors

c) Support for visually impaired through audio guidance and Braille stickers

d) Display of fare deducted, remaining balance, and ticket type

**9.7 Vendor & Operational Support**

Approved Indian system integrators such as CDAC, BEL, Trimax, Datamatics, Aurionpro, and Tummoc may be engaged for fare system deployment. System must provide:

a) ≥98% uptime via SLA

b) Remote diagnostics and OTA firmware updates

c) Training and AMC support for staff

d) Maintenance logs to be maintained as per MoHUA/State Urban Transport directives

### 9.8 Interoperability in Indian Ecosystem

Fare systems must interoperate with:

a) Metro Rail systems (BMRCL, etc.)

b) City BRT and feeder services

c) State-run city apps and mobility-as-a-service (MaaS) platforms

d) Integration with DigiYatra / UMTA platforms wherever applicable

## 10. Telecommunication & Passenger Information System (PIS) – Indian Context

To support the safe, efficient, and commuter-friendly operation of Neo-Bus services, a fully integrated **Telecommunication and Passenger Information System (PIS)** is essential. This system is envisioned to operate seamlessly within India's smart transport networks and must adhere strictly to Indian transport standards, especially **AIS-140** and directives issued by **MoRTH** and **Smart City Mission** guidelines.

Each bus will be fitted with a comprehensive onboard PIS designed to provide real-time, multilingual passenger updates through visual and audio formats. The information display system will include LED destination boards at the front, side, and rear of the vehicle, programmed to show route numbers and destinations in **Hindi, English, and kannada languages**. Internally, strategically mounted LED or LCD screens (minimum 18-inch) will display upcoming stops, estimated arrival times, emergency notifications, and city-specific alerts. These displays will work in coordination with a GPS-linked automatic announcement system that broadcasts information audibly in multiple languages.

A crucial part of the telecommunication setup is the **AIS-140 certified Vehicle Tracking Unit (VTU)**. This device will use real-time **GNSS (GPS/GLONASS/NavIC)** for accurate tracking and will be supported by 4G/5G cellular connectivity with fallback to 3G/2G to maintain uninterrupted communication. The unit will also monitor critical operating parameters via CAN bus interface and transmit location data to the central control system. The tracking unit will feature internal power backup for a minimum of two hours, geofencing capabilities, speed monitoring, and alert generation in case of route deviations or breakdowns.

For safety and fleet management, every Neo-Bus will include a **two-way communication system** that connects the bus driver with the central depot or Command & Control Center (CCC). This system enables instant communication in routine or emergency scenarios. Furthermore, **panic buttons** will be placed in the driver's area and passenger zone, sending immediate alerts to the CCC upon activation.

To ensure commuter safety, the telecommunication system will include a **CCTV surveillance setup** with a minimum of four IP-based HD cameras per vehicle. These cameras will cover the front, rear, mid-section, and driver cabin. They will be equipped with night vision and local storage capacity for up to 10 days of recording. Footage will also be retrievable via a secure network connection to the central system as needed.

In alignment with India's Digital India vision, **Wi-Fi hotspots** will be provided onboard, offering restricted, filtered internet access for passengers. These systems will be connected via local telecom operators such as **Jio, Airtel, or BSNL**, and monitored for uptime and data use through backend systems.

All these systems—PIS, VTU, CCTV, Wi-Fi, and voice communication—will be integrated into a centralized **Command & Control Center (CCC)**. This backend facility will collect, process, and visualize data in real-time, ensuring full visibility of fleet operations, passenger movement, and incident management. The CCC must be designed to support **MaaS (Mobility-as-a-Service) platforms**, open API integrations, and compliance with the **Urban Mobility data framework of MoHUA**.

To ensure safety, reliability, and interoperability, all hardware and software components of the telecommunication system must comply with relevant Indian regulations, including:

- **AIS-140** for vehicle tracking and emergency communication
- **IS 13252 Part 1 / IEC 60950** for electronics safety
- **WPC/DoT** certification for wireless components
- **DPDP Act 2023** for data protection
- **IS-9000 series** for environmental durability of hardware

Indian system integrators and vendors such as **Datamatics, L&T Smart World, CDAC, Trimax, NEC India**, and hardware partners like **Matrix, CP Plus, and RailTel** should be engaged to ensure indigenous compliance, data hosting, and lifecycle support.

**j) Emergency medical services**

The Concessionaire shall, at its own cost, construct a medical aid post at each Intermodal Hub location (Administrative Block with round-the-clock services) with a minimum size of 5 x 5 sq.m with a toilet (to be used for the patients of minimum size of 3 x3 sq.m) and hand it over to the Authority, no later than 30 (thirty) days prior to PCOD/COD. The Medical Aid Post(s) shall be deemed to be part of the project and shall be a vest in the Authority.

Two numbers of Ambulance shall be provided in a stretch. The Ambulance shall be brand new with fuel, driver, medical staff and insurance all-inclusive for the entire concession period. Ambulance fitted with GPS and GSM based vehicle tracker system shall be provided to be integrated with the SCADA System, along with all necessary manpower (including paramedical staff), medicines, equipment's etc. and shall be maintained in an effective manner throughout the concession period starting from the appointed date.

**k) Crane Service**

Crane Service shall be provided on Project Tunnel, as specified in the manual Clause 12.12. One number crane shall be provided in the stretch including fuel, driver, and insurance all-inclusive for the entire concession period.

**l) Authority & Independent Engineer's Offices**

a) Office Spaces: The concessionaire shall provide office spaces for the Authority and Independent Engineer with a minimum area of 500 sqm. during the construction period and a minimum area of 250 sqm. during the O&M period. The offices shall be complete with all fitting fixtures, lighting, furniture, and water supply, Internet Connection etc. The Concessionaire shall equip the conference hall in the office building with LCD screens as per the authority's requirement.

b) The concessionaire shall provide and maintain two vehicles (fuel driver and maintenance) during the concession period for the Authority. The vehicle shall be brand new SUV approved by the Authority. The vehicle shall be available to the Authority at any time 7 days per week.

c) The Employer and the Engineer shall designate a maximum of fifteen numbers of their computers for installation, by the Concessionaire, of software programs that the Concessionaire intends to use for document control, design, programming, production of drawings, etc. All software shall be originals and licensed by the manufacturer and issued and installed at the Concessionaire's cost.

**m) Digital Tools for Project Monitoring**

The Concessionaire shall design and commission the digital delivery system for effective information for all stages of the project development.

a) The system shall essentially comprise of Project Performance Management System (PPMS) which shall be duly integrated with the federated BIM model at appropriate Level of Detailing (LOD). Clients will have the final authority on deciding the PPMS to be implemented in this project. It will be a cloud-based system and should have the necessary accreditation/ empanelment from the relevant Ministry. PPMS should have functionality to support the distribution process i.e. transmittals and submittals. The system should have the ability to read and interface with CAD and BIM 3D model software.

b) Building Information Modelling (BIM) be mandatorily utilized during the design, construction, operations, and maintenance stage. BIM shall be facilitated with due consideration to 3D modelling, designing, working drawing, information framework, supervision and approvals, quantity survey and approvals, project implementation planning, construction planning, construction material and vendor management, etc. The drawing shall be extracted from the federated 3D models developed by various stakeholders of the supply chain.

c) The Concessionaire needs to ensure progress is updated in PPMS on a daily basis and related BIM model should also get updated. Based on "as built" drawing, "as built" BIM model should also be updated by Concessionaire.

**d)** The Concessionaire shall provide training to the Employer and any Engineer appointed by the Employer to enable them to make proper use of any software and training for any new version such as PPMS, BIM model and any other digital tools used in the Project.

**n) Interfacing Agencies and Management**

The Concessionaire shall be responsible for coordinating his design, technical, programming and construction activities with the Concessionaire of the adjacent package of the same project i.e., the interfacing Concessionaire. Secondly, the Concessionaire in addition to coordinating with the interfacing Concessionaire as defined above is also required to coordinate with the other organization who are involved in any of the activities, works or approvals that may affect and / or are affected by the works of the organization i.e., interfacing agencies are also required to be carried out by him. The organization means (a) Govt. of India Departments with whom the Concessionaires are required to liaise, (b) Govt. of Karnataka departments and (c) Private sector utility providers. The concessionaire shall develop an Interface management plan in consultation with the Authority/ Independent Engineer (IE).

**o) Traffic Management**

The Concessionaire shall plan his work in a manner to minimize disruption to road and the necessary care should be taken to divert the vehicle through the diversion road during construction, during muck dumping and during excavation work at the project site. The Concessionaire shall prepare a traffic management plan (based on his proposed construction methodology) which need to be approved by the Engineer and concerned Traffic Police Offices including Interfacing Concessionaire for the other package in the same project. To facilitate the proper traffic movement temporary road diversion, and temporary road decking shall be provided wherever necessary.

**p) Logo**

B-SMILE logo at a minimum of 5% segments is required.

**q) Art / Murals Work**

A minimum total Area of murals/Artwork around 600 sqm shall be provided.

Artwork is to be provided in the form of indoor sculpture / outdoor sculpture, Wall Murals, Glass mosaic tile and cut-glass mosaic etc. on all the entry-exits of Project Tunnel. The Concessionaire shall prepare specifications, methodology, sketches, 3D models etc. and any other relevant details and get approval of the Authority before execution.

**Artwork with Glass Mosaic Tiles**

**1. Glass Mosaic Tiles**

Tiles shall be composed of 100% glass, sourced from soda-lime, silica, or recycled glass material. The material must be non-porous, non-reactive, and stable under UV and moisture exposure (particularly for outdoor or wet-area applications). Standard size of tiles shall range from 12mm x 12mm to 50mm x 50mm. Thickness of the tiles typically ranges between 3mm and 6mm. Custom art works may use thicker glass tiles for 3D-effects. Tolerance on dimensions should not exceed ±0.5mm to ensure consistent grout joint spacing. The tile finish can be glossy/clear for depth and brilliance, matte/frosted for muted, soft appearances; Iridescent for light-reflective and color-shifting effects; and Textured/Patterned for tactile surface effects or light diffusion, as approved by Independent Engineer. All finishes should be scratch-resistant and maintain integrity under cleaning.

Tile edges may be straight cut for tight, uniform spacing, tumbled or rounded for a weathered, antique look, edge sharpness should be mitigated to ensure safety during installation and final display.

Glass tiles must be UV-resistant with stable pigments or colored substrate. Color variation should be

controlled within manufacturer-specified tolerance. For custom artwork, artists may use hand-colored or fused-glass tiles, if approved by Independent Engineer.

**2. Substrate and Backing Systems**

Interior Walls: Cement board, plaster, or properly sealed drywall. Interior Floors: Plywood (underlayment grade), concrete slab, or cementitious backer board. Exterior Applications: Concrete, cement board, or brick walls with waterproof membranes. Sculptural substrates: Polystyrene coated in fiberglass mesh and mortar; or shaped concrete panels. Substrates must be clean and free of dust, grease, or efflorescence, Flat within 3mm over 3metre for proper adhesion. Primed or sealed if porous or moisture sensitive.

Mounting Systems shall be paper-faced tiles (face-mounted): Provide clean grout lines and are recommended for wet areas, mesh-backed tiles: Easier to handle but must be tested for adhesive compatibility or dot-mounted or film-faced tiles may be used for temporary positioning during dry fitting. For artisan work, individual hand-placement (unglued, direct method) allows the highest detail.

**3. Adhesives and Mortar –**

White polymer-modified thin-set mortar (ANSI A118.4 or A118.15 compliant). Color: White is preferred to prevent shadowing through transparent or light-colored glass. The mortar should have high bond strength, flexibility for thermal expansion and contraction and non-sag for vertical applications. The mortar shall be applied using a 3mm V-notch trowel for even distribution, using the "back-buttering" technique on large or uneven tiles and the open time should not exceed 20–30 minutes; the tiles should set within working time. The tile work shall be cured for at least 24–48 hours before grouting, depending on temperature and humidity.

**4. Grouting:**

Grout for the glass mosaic tiles can be unsanded grout for joints ≤ 3mm; avoids scratching glass, sanded grout for joints > 1/8", provided tiles are not easily scratched or epoxy grout (ANSI A118.3), use of particular grout shall be selected and approved by Independent Engineer considering high-moisture or commercial areas due to superior strength, stain resistance, and water impermeability. Joint width shall be 1.5mm to 3mm consistent spacing is crucial for aesthetic balance and structural integrity. Grout Application shall be pressed into joints using a rubber float, holding it at a 45° angle. The surface shall be cleaned with damp sponge within 10–15 minutes to avoid hazing. For glass tiles with a textured or grooved surface, pre-sealing or masking shall be done. Glass tiles generally do not require sealing, subject to manufacturer's specifications. For sealing penetrating sealer shall be used on grout joints in case of cementitious grout.

**5. Finishing and Framing**

Complementary or contrasting border tiles to frame the mosaic artwork. For wall art or installations, aluminum or stainless-steel trim profiles shall be used as approved by Independent Engineer. For standalone artworks rigid framing shall be provided with reinforced back panels. For murals, edge protectors shall be incorporated if exposed to traffic or abrasion. Protective Measures material shall be covered with foam or non-abrasive material during transportation and after installation tiles shall be cleaned with pH-neutral cleaner, acids, alkalis, or abrasives shall be avoided.

**6. Artistic and Design Considerations**

Artwork shall be developed at full scale or created a to-scale template. Software like Mosaic Creator, Adobe Illustrator, or CAD may be used for layout planning. For large works, modular sections shall be created for easier installation.

Consider how natural or artificial light interacts with transparent or iridescent tiles. Blend similar tones for gradients; use contrasting tiles for emphasis or outlines. Use wheeled mosaic nippers for curves and shaping. For precision cuts, a glass score-and-break system or wet saw with glass blades are ideal. Always smooth sharp edges using a glass stone or diamond pad.

**7. Safety and Environmental Considerations**

The workers shall wear cut-resistant gloves and safety goggles during cutting, they will use dust masks when dry cutting or sanding backing boards. Proper ventilation shall be ensured when using adhesives or epoxy and the workspace shall be kept clean and organized to prevent injury from glass shards. The sharp tile fragments shall be collected and safely disposed of in puncture-proof containers.

# SCHEDULE – D

# SCHEDULE – D

## Annex – I

## (Schedule – D)

Specifications and Standards for the construction of TBM bored, Cut & Cover, and NATM tunnels, shafts, Underground Ramps and other underground structures.

## Section 1

## Specification and Standards

### 1.1 Preamble

This section covers Construction Specifications for Roads and should be read in conjunction with all other Documents constituting the Concession – viz. Invitation for Bids (NIT), Instructions to Tenderers, Conditions of Concession, Design Specifications, Construction Specifications, Drawings and other related documents. These Specifications given herein apply for elements of Road and Road structures.

### 1.2 Site Information

The information given hereunder and provided elsewhere in these documents is given in good faith by the Authority, but the Concessionaire shall satisfy himself regarding all aspects of site conditions and no claim will be entertained on the plea that the information supplied by the Authority is erroneous or insufficient.

The area in which the work is located is in plain/rolling terrain and lies in the city limits of Bengaluru.

### 1.3 General Climatic Conditions

a) Bengaluru has an equable climate throughout the year with occasional extreme weather events like heatwaves, cold waves, floods and droughts. The highest temperature ever recorded in Bengaluru is 41.8°c on April 30, 2024 in Kengeri at Bengaluru.

b) The hottest summer day on average has a maximum temperature of about 37°c, and the coldest winter day has a temperature of about 13°c. Occasionally, heat waves can cause temperatures of up to 38-40°c. Occasional cold waves will be leading to the temperatures as low as below 9-10°c. Bengaluru receives about 970 mm of rain annually, with the wettest months being August, September and October. The heaviest rainfall recorded in a 24-hour period was 18 cm recorded on 1988.

### 1.4 Manual of specifications and standards to apply

All materials, works and construction operation shall conform to the Manuals of Specifications and Standards IRC SP 87-2019, IRC:86-2018, IRC: SP: 91-2019, IRC: SP: 118-2018, Published by IRC (referred to as "Manuals" in this Schedule) and MoRTH Specification for Road and Bridge Works.

### 1.5 Deviations from the Manual

Notwithstanding anything to the contrary contained in Paragraph 1.1 to 1.4 above, the following Specifications and Standards shall apply to the Project Highway and for purposes of this Agreement, the aforesaid Specifications and Standards shall be deemed to be amended to the extent set forth in sections hereinafter.

### 1.6 Codes and Standards

**Table 1.1 Reference to the Standard Codes of Practice from:**

| | |
|---|---|
| MORTH | Ministry of Road Transport and Highways |
| IRC | Indian Road Congress |
| ASCE | American Society of Civil Independent Engineers |
| ASME | American Society of Mechanical Independent Engineers |

| | |
|---|---|
| ASTM | American Society for Testing Materials |
| BS | British Standard |
| CPWD | Central Public Works Department |
| DIN | Deutsches Institut für Normung e.V. |
| IRC | Indian Road Congress |
| IRCEM | Institution de Retraite Complementarie des Employes de |
| | Particular |
| IRS | Indian Railway Standards |
| IS | Indian Standards |
| MORTH | Ministry of Road Transport and Highways |
| UIC | International Union of Railways |

**Table 1.2 Applicable Codes, Standards & Publications**

| Code No. | Title |
|---|---|
| IS 875 Part I | Dead Loads - Unit weights of building Materials and stored materials. |
| IS 875 Part II | Imposed loads |
| IS 875 Part III | Wind Loads |
| IS 875 Part IV | Special Loads and Combinations |
| IRC:6 | Standard Specifications and Code of Practice for Road Bridges |
| IRC:16 | Standard Specification and code of Practice for Prime and Tack Coat (Second Revision) |
| IRC:19 | Standard Specification and code of Practice for Water Bound Macadam (Third Revision) |
| IRC: 35 | Code of Practice for Road Markings |
| IRC:37 | Guidelines for the Design of Flexible Pavements |
| IRC:38 | Guidelines for Design of Horizontal Curves for Highways and Design Tables |
| IRC:58 | Guidelines for the Design of Rigid Pavements for Highways |

| | |
|---|---|
| IRC:67 | Code of Practice for Road Signs |
| IRC:69 | Space standards for Roads in Urban areas |
| IRC:70 | Guidelines on Regulation and Control of Mixed Traffic in Urban Areas |
| IRC:86 | Geometric design standards for urban roads and streets |
| IRC:92 | Guideline for Design of Interchanges in Urban areas |
| IRC:93 | Guidelines on Design and Installation of Road Traffic Signals |
| IRC:98 | Guidelines on accommodation of Utility Services in Urban Areas |
| IRC:102 | Traffic Studies for Planning Bypasses around Towns |
| IRC:103 | Guidelines for Pedestrian Facilities |
| IRC:106 | Guidelines for Capacity of Urban Roads in Plain Areas |
| IRC: SP:23 | Vertical curves for Highways |
| IRC: SP:41 | Guidelines on Design of At-Grade Intersections in Rural and Urban Areas |
| IRC: SP:42 | Guidelines on Road Drainage |
| IRC: SP:43 | Guidelines on Low-cost Traffic Management Techniques for Urban Areas |
| IRC: SP:49 | Guidelines for the Use of Dry Lean Concrete as Sub-base for Rigid Pavement |
| IRC: SP:50 | Guidelines on Urban Drainage |
| IRC: SP:61 | An Approach Document on Whole Life Costing for Bridges in India |
| IRC: SP:63 | Guidelines for the Use of Interlocking Concrete Block Pavement |
| IRC: SP-87 | Manual of Specifications & Standards for Six Laning of Highways Through Public Private Partnership. |
| IRC: SP:88 | Manual on Road Safety Audit |
| IRC: SP:92 | Guidelines for the Design of Interchange in Urban Areas |
| IRC: SP:112 | Manual for Quality Control in Road and Bridge works |
| IRC: SP:118 | Manual for Planning and Development of Urban Roads and Streets |
| | **CODES OF DESIGN AND FABRICATION FOR PRE - INDEPENDENT ENGINEERED BUILDING** |

| | |
|---|---|
| IS 800: 2007 | General construction in steel |
| IS 808: 1989 | Dimensions for hot Rolled steel sections |
| IS 801 : 1975 | Code of Practice for use of Cold Formed light gauge steel structural members in general building |
| IS 811 | Code of Practice for use of Cold Formed light gauge structural steel sections |
| AISC: 2000 | Design code |
| IBC | Indian Building code |
| AISI:2001 | Purlin Code |
| ANS:2006 | Welding Code |
| SP-38: (S&T) | Handbook of typified designs for structures with steel Roof Code |
| IS 816 | Code of Practice for use of metal arc welding for general ·- construction in mild steel |
| IS 456 | Plain and Reinforced Concrete Code of Practice |
| IS 1893 | Criteria for Earthquake resistant design of structures |
| IS 6403 | Code of Practice for determination of bearing capacity of shallow foundations |
| IS 1786 | Specification for high strength deformed steel bars and wires for concrete reinforcement |
| IS 13920 | Code of practice for ductile detailing of reinforced concrete Structures subjected to seismic forces |
| SP-16 | Design aids for reinforced concrete to IS 456. |
| SP-34 | Handbook on concrete reinforcement and detailing |
| | All relevant BIS Code of India for Civil, Electrical, Water Supply, Sanitary, HVAC and Solar Panels. |
| SP-35 | Handbook of Water Supply and Drainage, BIS, |

## 1.7 Deviations from the Manual and Codes

**Deviations needed to be updated .**

| S No. | Clause referred in manual | Item | Modified Provision |
|---|---|---|---|
| 1 | 2.5 | Median | As per typical cross section given in |

| S No. | Clause referred in manual | Item | Modified Provision |
|---|---|---|---|
| | | | Schedule-B. |
| 2 | 2.6 | Shoulders | As per typical cross section given in Schedule-B. |
| 3 | 2.16 | Utility Corridor | Utility corridor width shall be as per typical cross section given in Schedule-B |
| 4 | 2.17 | Typical Cross – Section | Typical cross section shall be as per Schedule-B. |
| 5 | Clause 2.e of Appendix-B of IRC:SP:91-2019 | Footpath | One footpath of 750 mm wide and raised 340 mm from road level is to be provided. |

**1.8 The work shall include but not be limited to:**

a) Survey and Setting out of the Alignment

b) Additional Exploratory Geotechnical Investigations along the alignment of the tunnels and cut and cover portions etc., if necessary,

c) Excavation of Open Cuts in all types of soils and rock including provision of treatment such as Soil Nailing, Rock bolting, Installation of Wire Netting, Shotcreting, grouting etc. to the excavated profile as and where necessary as per approved design, drawings and as directed by the Independent Engineer.

d) Tunnel Excavation in all types of soils and rock with concurrent Advance Probing and if and where necessary, Grouting of the Strata ahead, F-ore-poling, Shotcreting, Rock bolting and installation of Permanent Steel Supports with precast Lagging and Lean Concrete back-packing, installation of Lattice Girder Supports embedded in S.F.R. Shotcrete, as and where necessary as per approved design, drawings and as directed by the Independent Engineer.

e) Construction of Cut & Cover Portion and Concrete Portals with Backfill behind with drainage arrangements, in the Approach Cuts.

f) Concrete Lining of the tunnel where required and as directed by the Independent Engineer.

g) Concrete side Drains/ cover Drains, Kerbs and Crash Barrier etc. in the Tunnels, Cut & Cover Portions and Open Cuts.

h) Installation of Furnishings such as Walkway Slabs, Hand Railing for the Walkways, Fire Water Line etc. in the Tunnels, Cut & Cover Portions and Open Cuts.

i) Design, Supply, Erection, Testing and Commissioning of Mechanical, Electrical and Plumbing Services.

## Section 2

## Road Works

### 2.1 MORTH Specifications for Road Works

a) The General Technical Specifications for Road works shall be the "Specifications for Road and Bridge Works" (Fifth Revision, 2013) issued by the Ministry of Road Transport and Highways, (MoRTH), Government of India, and published by the Indian Roads Congress (IRC). Latest editions with corrections and amendments up to date to the extent they are applicable to the Road works covered under scope of works. Further the specifications for Road works contained herein for some of the items of work will supersede the provisions of the MORTH Specifications for Road works to the extent of their applicability.

b) Where reference is made in the Concession to specific standards codes to be met by the materials, plant, and other supplies to be furnished, and work performed or tested, the provisions of the latest current edition or revision of the relevant standards as on date of tender and codes in effect shall apply, unless otherwise expressly stated in the Concession. Where such standards and codes are national, or relate to a particular country or region, other internationally recognized standards which ensure a substantially equal or higher performance than the standards and codes specified will be accepted subject to the Independent Engineer's prior review and written Notice. The difference between the standards specified and the proposed alternative standards must be fully described in writing by the Concessionaire and submitted to the Independent Engineer at least 28 days prior to the date when the Concessionaire desires the Independent Engineer's Notice. In the event the determines that such proposed deviations do not ensure substantially equal performance, the Concessionaire shall comply with the standards specified in the documents.

### 2.2 Amendments/Modifications/Additions to Existing Clauses of General Technical Specifications.

a) The amendments to General Technical Specifications for Road works shall comprise of various Amendments/Modifications/Additions to the "Specifications for Road and Bridge Works" referred to in Para 2.1 above and Additional Specifications for particular item of Road works not already covered in General Technical Specifications.

b) A particular Clause or a part thereof in "Specifications for Road and Bridge Works (Fifth Revision, 2013)", as corrected in the original referred in Para 2.1 above, where Amended/Modified/Added upon, and incorporated, such Amendment/ Modification/ Addition supersedes the relevant Clause or part of the Clause.

c) The Additional Specifications shall comprise specifications for particular items of work not already covered in General Technical Specification.

d) When an Amended/Modified/Added Clause supersedes a Clause or part thereof in the said Specifications, then any reference to the superseded Clause shall be deemed to refer to the Amended/Modified/Added Clause or part thereof.

### 2.3 Pavement Construction

#### A. General

Sourcing of all materials as well as compliance with environmental requirements under the applicable laws in respect of all works to be executed under the Bid Document shall be the sole responsibility of the Concessionaire. All materials, whether natural (such as earth, gravel, sand, aggregates etc.), processed (such as bituminous and concrete mixes), or manufactured (such as cement, steel, bitumen etc.) shall be incorporated into the work only if they are tested from recognized NABL lab and found to meet the requirements of this Tender Document or, in the absence of any provision in this Tender

Document, conform to the best industry practice.

**B. Construction of Rigid Pavement**

**1. Consolidation of subgrade**

a. The sub-grade shall be consolidated with a power road roller of 8 to 12 tonnes. The roller shall run over the sub-grade till the soil is evenly and densely consolidated and behaves as elastic mass (the roller shall pass a minimum of 5 runs on the sub-grade). All the undulations in the surface that developed due to rolling shall be made good with material or quarry spoils as the case may be and the sub-grade is re-rolled.

b. Surface Regularity: The finished surface shall be uniform and conform to the lines, grades and typical cross-sections shown in the drawings. When tested with the template and straight edge, the variation shall be within the tolerances specified in the table below:

Table 2.1: Tolerance limit of variation in finished surface

| Sl. No. | Profile | Property | Value |
|---|---|---|---|
| 1 | Longitudinal Profile | Maximum Permissible undulation when measured with a 3 m straight edge | 24 mm |
| 2 | Cross Profile | Maximum Permissible variation from specified | 15 mm |

c. When the surface irregularity of the sub-grade falls outside the specified tolerances, the Concessionaire shall rectify these with fresh material or quarry spoils as the case may be, and the sub-grade re-rolled to the satisfaction of the Independent Engineer.

**2. Base course (WMM)**

a) The construction operations shall be carried out as per clause 406 of MORTH Specifications for Road and Bridge Works.

b) This work shall consist of laying and compacting clean, crushed, graded aggregate and granular material, premised with water, to a dense mass on a prepared subgrade/sub- base/base or existing pavement as the case may be in accordance with the requirements of these specifications. The material shall be laid in one or more layers as necessary to lines, grades and cross-sections shown on the approved drawings or as directed by the Independent Engineer.

c) The thickness of a single compacted Wet Mix Macadam layer shall not be less than 75 mm. When vibrating or other approved types of compacting equipment are used, the compacted depth of a single layer of the sub-base course may be increased to 200mm upon approval of the Independent Engineer. The aggregates shall conform to the grading given below.

d) Preparation of Base: The base of the sub-grade/sub-base/base shall be prepared to the specified lines and cross fall (camber) and made free of dust and other extraneous material. Any ruts or soft yielding places shall be corrected in an approved manner and rolled until firm surface is obtained, if necessary, by sprinkling water.

e) Preparation of lateral confinement of aggregates: While constructing WMM, arrangement shall be made for the lateral confinement of wet mix. This shall be done laying materials in adjoining shoulders along with that of WMM layer.

f) Preparation of Mix: WMM shall be prepared in an approved mixing plant of suitable capacity having provision for controlled addition of water and forced/positive mixing arrangement like pug mill or

pan type mixer of concrete batching plant. For small quantity of wet mix work, the Independent Engineer may permit the mixing to be done in concrete mixers.

g) Optimum moisture for mixing shall be determined in accordance with IS: 2720 (Part 8) after replacing the aggregate fraction retained on 22.4mm sieve with material of 4.75mm to 22.4mm size. While adding water, due allowance should be made for evaporation losses. However, at the time of compaction, water in the wet mix should not vary from the optimum value by more than agreed limits. The mixed material should be uniformly wet, and no segregation should be permitted.

h) Spreading of mix: Immediately after mixing, the aggregates shall be spread uniformly and evenly upon the prepared sub-grade/sub-base/base in required quantities. In no case should these be dumped in heaps directly on the area where these are to be laid nor shall their hauling over a partly completed stretch be permitted.

i) The mix may be spread by motor grader. For portions where mechanical means cannot be used, manual means as approved by the Independent Engineer shall be used. The motor grader shall be capable of spreading the material uniformly all over the surface. Its blade shall have hydraulic control suitable for initial adjustments and maintaining the same so as to achieve the specified slope and grade.

j) The surface of the aggregate shall be carefully checked with templates and all high or low spots remedied by removing or adding aggregate as may be required. The layer may be tested by depth blocks during construction. No segregation of larger and fine particles should be allowed. The aggregates as spread should be of uniform gradation with no pockets of fine materials.

k) Compaction: After the mix has been laid to the required thickness, grade and cross fall/camber the same shall be uniformly compacted, to the full depth with suitable roller. If the thickness of single compacted layer does not exceed 100 mm, a smooth wheel roller of 80 to 100 KN weight may be used. For a compacted single layer up to 200 mm, the compaction shall be done with the help of vibratory roller of minimum static weight of 80 to 100 KN or equivalent capacity roller. The speed of roller shall not exceed 5km/h.

l) In portions having a unidirectional cross fall/super-elevation, rolling shall commence from the lower edge and progress gradually towards the upper edge. Thereafter, roller should progress parallel to the center line of the road, uniformly overlapping each preceding track by at least one-third width until the entire surface had been rolled. Alternate trips of the roller shall be terminated in stops at least 1 m away from any preceding stop.

m) In portions in camber, rolling should begin at the edge with the roller running forward and backward until the edges have been firmly compacted. The roller shall then progress gradually towards the center parallel to the centerline of the road uniformly overlapping each of the preceding track by at least one third width until the entire surface has been rolled.

n) Any displacement occurring as a result of reversing of the direction of a roller or from any other cause shall be corrected at once as specified and/or removed and made good. Along forms, kerbs, walls or other places not accessible to the roller, the mixture shall be thoroughly compacted with mechanical tempers or a plate compactor. Skin patching on an area without scarifying the surface to permit proper bonding of the added material shall not be permitted.

o) Rolling shall not be done when the subgrade is soft yielding or when it causes a wave like motion in the sub-base/base course or subgrade. If irregularities develop during rolling which exceeds 123 mm when tested with a 3 m straight edge, the surface should be loosened, and premixed material added or removed as required before rolling again as to achieve a uniform surface conforming to the desired grade and cross fall. In no case should the use of unmixed materials be permitted to make up the depressions. Rolling shall be continued till the density achieved is at least 98% of the maximum dry

density for the material. After completion, the surface of any finished layer shall be well-closed, free from movement under compaction equipment or any compaction planes, ridges, cracks and loose material. All loose, segregated or otherwise defective areas shall be made good to the full thickness of the layer and re-compacted.

p) Setting and Drying: After final compaction of wet mix macadam course, the road shall be allowed to dry for 24 hrs.

q) Opening to traffic: No vehicular traffic of any kind should be allowed on the finished wet mix macadam surface till it has dried and the wearing course laid.

**3. Dry Lean Concrete (DLC)**

a) Moisture Content: The optimum water content shall be determined and demonstrated by rolling during trial length construction and the optimum moisture content and degree of compaction shall be got approved from Independent Engineer. While laying in the main work, the lean concrete shall have a moisture content between the optimum and optimum +2 percent, keeping in view the effectiveness of compaction achieved and to compensate for evaporation losses.

b) Cement Content: The minimum cement content in the lean concrete shall not be less than 150 Kg/cum of concrete. If this minimum cement content is not sufficient to produce concrete of the specified strength, it shall be increased as necessary without additional cost compensation to the Concessionaire.

c) Concrete Strength: The average compressive strength of each consecutive group of 5 cubes made in accordance with Clause No. 903.5.1.1 of MORTH Specifications shall not be less than 10 MPa at 7 days. In addition, the minimum compressive strength of any individual cube shall not be less than 10 MPa at 7 days. The design mix complying with the above Clauses shall be got approved from the Independent Engineer before 30 days of commencement of work and it shall be demonstrated in the trial length for construction of 150 mm thick Dry Lean Concrete.

**4. Cement Concrete Pavement (PQC)**

a) Cement Content: Cement as per clause 4.2.1 above is used, the quantity of cement shall not be less than 360 kg/cum. If this minimum cement content is not sufficient to produce concrete of the specified strength, it shall be increased as necessary by the Concessionaire at his own cost.

b) Concrete Strength: The characteristic flexural strength of Pavement Quality concrete shall not be less than 4.5 MPa unless specified otherwise. Target mean flexural strength for mix design shall be more than 4.5 MPa + 1.65s, where s is standard deviation of flexural strength derived by conducting test on minimum 30 beams. The design mix complying with the above clauses shall be got noticed by the Independent Engineer before 30 days of commencement of work and it shall be demonstrated in the trial length for construction for 350 mm thick Pavement Quality Concrete.

c) Steel for Dowels and Tie Bars: Steel shall conform to the requirements of IS:432 and IS: 1786 as relevant. The dowel bars shall round MS Bars conform to IS:432 of Grade I. Tie bars shall be High yield Strength Deformed bars conforming to IS:1786 and grade of Fe 500 or plain bars conforming to IS:432 of Grade I.

**5. Formwork**

a) All side forms shall be of mild steel channel sections of depth equal to the thickness of the pavement. The length of form shall not be less than 3 m except in the case of installations along curves. Wooden forms shall be capped along the inside upper edge with 30-50 mm angle iron well recessed and kept flush with the face of the wooden forms. The forms shall be held firmly in place by stakes driven to the ground. The supply of forms shall be sufficient to permit them to be taken out only 12 hours after the concrete has been placed. Any unevenness in the formwork, particularly the top will affect riding quality. All forms shall be cleaned and oiled each time they are used. The forms shall be jointed

neatly and set correctly to the required grade and alignment.

**6. Sections**

a) The Sections shall have a length of at least 3 m except on curves of less than 45 m radius, where shorter sections may be used. When set to grade and staked in place, the maximum deviation of the top surface of any section from a straight line shall not exceed2 mm in the vertical plane and 5 mm in the horizontal plane. The method of connection between sections shall be such that the joint formed shall be free from difference in level, play or movement in any direction. The use of bent, twisted or worn-out forms will not be permitted. At least three stake pickets for each 3 m of form and the bracing and support must be ample to prevent springing of the forms under the pressure of concrete or the weight or thrust of machinery operating on the forms.

b) The forms shall be jointed neatly and shall be set with exactness to the required grade and alignment. Both before and after the forms are placed and set, the subgrade or sub-base under the forms shall be thoroughly tamped in an approved manner. Sufficient rigidity shall be obtained to support the forms in such a position that during the entire operation of compacting and finishing of concrete they shall not at any time deviate more than 3 mm from a straight edge 3 m in length. Forms which show a variation from the required rigidity or alignment and levels shown in the drawing, shall be reset or removed, as directed. The length and number of stakes shall be such as to maintain the forms at the correct line and grade. All forms shall be cleaned and oiled each time before they are used. Forms shall be set ahead of the actual placing of concrete for the entire day's work. Provision for transverse/longitudinal joints shall be arranged while setting up the formwork.

**7. Placement of steel**

a) In placing reinforcing steel, the initial layer of concrete shall be struck off to the entire width of the slabs and of sufficient length to permit sheet or mat of reinforcement to be laid full length without further manipulations of the reinforcement. Displacement of the reinforcement during concreting operations shall be prevented.

b) The type and grade of reinforcement to be used shall be as indicated on the drawings. Where this information is not given on the drawings, hot rolled deformed bars having yield strength of 415 MPA shall be used. Bars shall be bent cold (no heating shall be permitted), correctly and accurately to the size and shape as shown on the detailed drawings or as directed by the Independent Engineer.

c) Overlapping of bars shall be as indicated on the drawings. The overlapping bars shall not touch each other, and these shall be kept apart by 25mm or 1.25 times the maximum size of the coarse aggregate whichever is greater, with concrete between them. But where this cannot be done, the overlapping shall be bound together at intervals not exceedingly twice the dia. of such bars, with two strands of annealed steel wire of 0.90 mm to 1.6 mm thickness twisted tight. The overlaps shall be staggered for different bars and located at points, along the span, where neither shear nor bending moment is maximum.

d) The ends of rods shall be bent into semi-circular hooks, having clear diameter equal to four times the diameter of the bar, with a length, beyond the bend equal to four times the diameter of the bar. End hooks may, however, not be provided for cold twisted, hot rolled and CRS bars.

e) Welding should not be used unless absolutely necessary. Reinforcement bar does not weld very well, and the resulting splice can be a week spot. Binding is better as welding can produce a reduction in strength as well.

f) Reinforcement bars shall be placed in position as shown in the drawings. The bars crossing one another shall be tied together at every intersection with two strands of annealed steel wire 0.90 to 1.6 mm thickness twisted tight to make the skeleton of the steel work rigid so that the reinforcement does not get displaced during the deposition of concrete.

g) In case of beam and slab construction, pre-cast cover blocks in cement mortar 1:2, about 4cm x 4cm section and of thickness equal to the specified cover shall be placed between the bars and shuttering, so as to secure and maintain the requisite cover of concrete over reinforcement.

**8. Concrete Plant Operation**

a) The batch plant can be a commercial concrete batch plant, or a temporary batch plant brought in and assembled by the Concessionaire near the paving site. On large concrete paving projects, most Concessionaire choose to mix their concrete using their own temporary batch plant. This is because commercial batch plants are usually too small to produce the large amount of concrete needed for a concrete paving project.

b) All batching of materials shall be by weight. After determining the proportion of ingredients for the field mix, the fine aggregate and each separated size of coarse aggregate shall be proportioned by weight in an approved weigh-batching plant and placed into the hopper of the mixer along with the necessary quantity of cement.

c) Cement shall be measured either by weight or by the bag as packed by the manufacturer. Where cement is measured by the bag, it is necessary to sample check the weight of the bags occasionally. All materials other than cement shall be calculated based on one or more whole bags of cement taking the weight of cement as 1440 kg/cu.m. Water may be measured by volume. Where it is unavoidable, volume batching of aggregates may be permitted as a special case in small projects.

d) The batching plant/concrete mixer shall be capable of proportioning the materials by weight, each type of material being weighed separately. The capacity of the batching and mixing shall be at least 25 percent higher than the proposed capacity for the laying arrangements. The rated capacity of the mixer shall not be less than 0.3 cum. The weighing mechanism shall be checked periodically and calibrated, to yield an accuracy of ± 2 percent in the case of aggregates and ± 1 percent in the case of cement, fly ash and water. When fly ash is added, the mixing time shall be increased by a minute to ensure proper mixing.

e) The mixing speed of the drum shall not be less than 15 revolutions per minute nor the peripheral speed of the drum greater than 60 m per minute. The sequence of loading shall be coarse aggregates, fine aggregates, cement, fly ash if used. After mixing dry, water will be released from the venturi meter.

**9. Hauling of mix**

a) The mix shall be discharged immediately from the mixer, transported directly using wheelbarrows or tippers to the point where it is to be laid and protected from the weather by covering with tarpaulin during transit.

b) Transportation of concrete mix from mixer to paving site with steel pans is not permitted in major works as the mix tends to get segregated during such handling. It is desirable to use wheelbarrows or trolleys for carrying mix to the paving site. The workability of the mix can be controlled better with the use of wheelbarrows.

c) The concrete shall be transported continuously to feed the laying equipment to work at a uniform speed in an uninterrupted manner.

**10. Equipment**

a) The concrete shall be placed with an approved fixed form or slip form paver with independent units designed to (i) spread, (ii) consolidate from the mould, screed and float- finish, (iii) texture and cure the freshly placed concrete in one complete pass of the machine in such a manner that a minimum of hand finishing will be necessary and so as to provide a dense and homogeneous pavement in conformity with the plans and Specifications.

**11. Placing Concrete**

a) Concrete shall be deposited on the sub-base to the required depth and width in successive batches and in continuous operation. Care shall be taken to see that no segregation of materials results.

b) Concrete shall be placed within one hour of the time of batching and before it has attained initial set. The temperature of the concrete when deposited in the forms shall be not less than 10°C or more than 30°C. Concrete shall not be placed either during rain or when the air temperature in the shade is below 5°C or above 35°C.

c) The placing and spreading shall be done by a paver. While being placed, the concrete shall be rodded with suitable tools so that the formation of voids or honeycomb pockets is avoided. In case of unavoidable interruption, a full depth transverse joint shall be made at the point of stoppage of work provided the section on which the work has been suspended is about 2 to 3 m long.

**12. Compaction**

a) The compaction shall be carried out immediately after the material is laid with the necessary surcharge (extra loose thickness) and leveled. The spreading, compacting and finishing of the concrete shall be carried out as rapidly as possible and the operation shall be so arranged as to ensure that the time between the mixing of the first batch of concrete in any transverse section of the layer and the final finishing of the same shall not exceed 90 minutes when the concrete temperature is above 25 and below 30°C and 120 minutes if less than 25°C.

b) Compaction shall be achieved by a vibrating hand screed. As soon as concrete is placed, it shall be struck off uniformly and screeded to the cross-section desired. Needle vibrators may be employed to ensure compaction near the forms. The entire surface shall then be vibrated with screed resting on the side forms and being drawn ahead with a sawing motion, in combination with a series of lifts and drops alternating with lateral shifts. Working of the vibrators shall be regularly checked and stand by shall always be maintained for emergency use. Segregated particles of coarse aggregate which collect in front of the screed shall be discarded. Under no circumstances shall such segregated particles be carried forward and pushed on to the base in front of the mass.

c) Immediately after the screeding has been completed and before the concrete has hardened, i.e. while the concrete is still in the plastic stage, the surface shall be inspected for irregularities with a profile checking template and any needed correction made by adding or removing concrete followed by further compaction and finishing.

d) After compaction has been completed, roller shall not stand on the compacted surface for the duration of the curing period except during commencement of next day's work near the location where work was terminated the previous day.

**13. Finishing**

a) In the case of normal concrete just before the concrete becomes non-plastic, the surface shall be belted with a two-ply canvas belt not less than 200 mm wide and at least 1 .0 m longer than the width of the slab. Hand belts shall have suitable handles to permit controlled uniform manipulation. The belt shall be operated with short strokes transverse to the carriageway centerline and with a rapid advance parallel to the centerline.

b) After belting, and as soon as surplus water, if any, has risen to the surface, the pavement shall be given a broom finish with an approved clean steel or fiber broom not less than 450mm wide. The broom shall be pulled gently over the surface of the pavement from edge to edge.

c) Adjacent strokes shall be slightly overlapped. Brooming shall be perpendicular to the centerline of the pavement and so executed that the corrugations thus produced shall be uniform in character and width, and not more than 1.5 mm deep. Brooming shall be completed before the concrete reaches such a stage that the surface is likely to be torn or unduly roughened by the operation. The broomed surface shall be free from porous or rough spots, irregularities, depressions, and small pockets, such

as, may be caused by accidentally disturbing particles of coarse aggregate embodied near the surface.

d) After belting and brooming have been completed, but before the concrete has taken its initial set, the edges of the slab shall be carefully finished with an edge tool of 6 mm radius, and the pavement edge left smooth and true to line.

**14. Curing of Concrete**

A. Immediately after the finishing operations have been completed, the entire surface of the newly laid concrete shall be covered against rapid drying and cured. Curing can be done by one of the following two methods:

a) By application of curing compound followed by spreading of wet hessian and moistening it regularly. In case of arid areas where water is extremely scarce, two applications of curing compound with moist curing by wet hessian may be allowed at the discretion of the Independent Engineer. Curing compound shall be resin based aluminized reflective type.

b) For small works, curing can be done by manual methods using wet hessian/ burlap or jute mats, which is kept moist during curing period. Curing shall be done for a minimum period of 14 days. In case of blended cement curing shall be done for 16 days. The water used for curing shall also be free from all injurious chemicals, like, chlorides and sulphates and shall meet the requirements of IS 456.

c) After the concrete has begun to harden i.e. about 1 to 2 hours after it's laying, it shall be protected from quick drying with moist gunny bags, sand or any other material approved by the Independent Engineer. After 24 hours of laying of concrete, the surface shall be cured by flooding with water of minimum 25mm depth, or by covering with wet absorbent material i.e. wet hessian cloth (minimum of two layers), burlap or jute mats.

d) The coverings used shall be of such length (or width) that when laid will extend at least 500 mm beyond the edges of the slab, shall be so placed that the entire surface and placed as soon as the concrete has set sufficiently to prevent marring of the surface. Prior to their being placed, the coverings shall be thoroughly wetted with water and placed with the wettest side down. They shall be sufficiently heavy so as to cause them to remain in intimate contact with the surface covered. They shall be maintained fully wetted and in position for 24 hours after the concrete has been placed, or until the concrete is sufficiently hard to be walked upon without suffering any damage.

e) To maintain the coverings wet, water shall be gently spayed so as to avoid damage to the fresh concrete. If it becomes necessary to remove the coverings for cutting the joints, the concrete slab shall not be kept exposed for a period of more than half an hour. The rate of evaporation of water from the PQC shall not be more than 1 kg/sq. m/hour to avoid plastic shrinkage cracking. Water curing shall be done for a minimum period of 14 days.

f) Worn coverings or coverings with holes shall not be permitted. If the covering is furnished in strips, the strip shall be laid to overlap at least 1 50 mm.

g) Walking on freshly laid concrete to facilitate placing coverings or any other use which could be otherwise done without using the freshly laid concrete at least up to 28 days will not be permitted to maintain the texture depth provided.

**15. Removal of Formwork**

a) Forms shall be removed only after the concrete has set for at least 12 hours. They shall be carefully removed without causing damage to the edge of the pavement. After the removal of forms, the ends shall be cleaned and any honey-combed areas pointed with 1:2 cement- sand mortar, after which the sides of the slab shall be covered with earth to the level of the slab. In

case the adjoining soil has more than 0.5 percent sulphates, the sides may be painted with a bituminous tack coat.

**16. Protection of Concrete**

a) The freshly laid concrete shall be protected by suitable barricades to exclude traffic. No heavy commercial vehicles carrying construction materials shall be allowed for a period of 28days. Tractor trailers without any construction materials and light commercial vehicles may be allowed after 14 days.

b) Any part of the pavement damaged by traffic or other causes occurring prior to its final acceptance shall be repaired or replaced in a manner satisfactory to the Independent Engineer.

17. **Joint Cutting:** The Joints of the Rigid pavement shall be designed & constructed as per IRC:58-2015 and as approved by Independent Engineer.

B. **Cement Concrete Wearing Coat:** Cement concrete wearing coat shall be laid separately over the Tunnel slab. The cement concrete wearing coat shall be designed for design traffic load. The minimum thickness of wearing a coat shall be 75 mm. The concrete shall be of minimum M30 grade. Steel reinforcement of 8 mm diameter at 150 mm spacing in both directions shall be provided at the mid depth of the wearing coat. In a length of 1 m near the expansion joint additional reinforcement of 8 mm diameter bars shall be provided in both directions to make the spacing as 75 mm. Cement concrete and steel reinforcement shall conform to Section 1700 and Section 1600 respectively of MoRTH Specifications:2013. Curing of wearing coat shall start as early as possible. All carriageway and footpath surfaces shall have non-skid characteristics. The cross slope in the deck shall be kept as 2.5 percent. In case of cement concrete wearing coat provide profile corrective course along with wearing coat in single layer.

Overlay on the existing wearing coat on bridge decks shall not be permitted. In case the wearing coat is damaged, it shall be repaired or replaced.

**C. Construction of Flexible Pavement**

**1. Setting Out**

a. All construction shall be done with reference to the final centerline of the main location survey. The centerline should be accurately referenced, every 50m interval in plain and rolling terrains, 20 m intervals in hilly terrains and at all curve points, by marker pegs and chainage boards set in or near the fence line. The schedule of reference dimensions shall be prepared, and marker pegs shall be maintained till the end of the work. Working benchmarks tied with the reference benchmark should be established at the rate of four numbers per km and at or near all drainage structures, other bridge and underpasses. An up-to-date record of all benchmarks shall be maintained, and the working benchmarks should be checked frequently.

b. On construction reaching the formation level stage, the centerline should again be set out and accurately referenced by marker pegs at the outer limits of the formation. Posts of timber or steel should be kept one metre from the formation edges showing the finished formation/ finished base course/finished road levels. It should be possible to stretch a thread across to verify the finished levels of various courses. All survey monuments, benchmarks, beacons, etc. should be maintained accurately during the construction process. A survey file containing the setting out data for traverse points and levels shall be prepared and maintained during the construction process.

c. Precision automatic levels, having a standard deviation of ± 2 mm per km and fitted with micrometer attachment shall be used for all double run levelling work. Setting out of the road alignment and measurement of angles shall be done by using Total Station with traversing target, having an accuracy of one second. Measurement of distances shall be done preferably using

precision instruments like Distomat. The work should conform to Clause 109 of MORTH Specifications for Road and Bridge Works.

**2. Earthwork**

a. Excavation for Roadway and Drainage - All materials in excavation are to be classified as one of the following:

1. Soil Ordinary rock (not requiring blasting)
2. hard rock (requiring blasting)
3. hard rock (blasting prohibited) and marshy soil.

This classification is based on the methods, tools and equipment required for excavation.

b. The area for the roadway and drainage excavation should be cleared and grabbed. Set out the limits of excavation true to lines, curve, slopes and grades and sections as shown on the drawings. Periodicals checks are to be done on the benchmarks and on the construction lines for accuracy. The work shall be so done that the suitable materials available from excavation are satisfactorily utilized as deemed fit. All reasonable precautions are to be taken for protection and preservation of any or all existing trees, drains, sewers, sub-surface drains, pipes, conduits, or any other structures which may be affected by construction operations. All adequate precautions are to be taken to guard against soil erosion, water pollution etc. and appropriate drainage measures are also to be taken. If water is met with in the excavation, it shall be removed by suitable diversions, pumping or bailing out and the excavation is to be kept dry.

**c. Preparation of cut formation**

1) Cut formation requires very close inspection for the reason that it is for the first time that the material gets exposed. Check the suitability of the natural material. Some shales may look hard when dry but get slushy in presence of water. If such unsuitable materials are met with, have these removed to a depth of at least 0.5 m or as otherwise specified and replaced with suitable material. If density of sub-grade is lower than specified density, it shall be loosened to a depth of 500 mm, recompacted in layers not less than 97 per cent of the maximum laboratory dry density as per clause 9.5.6. In rock formation all dish shaped cavities left out by blasting should be cut out at edges to facilitate drainage. Low areas should be filled up with sub-base material and properly compacted. Any seepage should be intercepted and properly drained. Earth work for excavation shall be carried out as per clause 301 of MORTH Specifications for Road and Bridge works.

d. **Excavation for Structures** - The points which require specific attention in excavation work are:

1) Setting out be true to lines, curves, slopes and levels.

2) Excavation shall be taken to the width of the lowest step of the footing including additional width as required for construction operation. The depth to which the excavation is to be carried shall be as shown in the drawing. Normally, open foundations shall be laid dry. Dewatering by bailing, pumping, diversion channels and other necessary works should be carried out when seepage flow is met with. Where cofferdams are required, these are to be safely designed and made watertight and should be carried to adequate depth and heights.

3) The discharged water should not cause damage to the works, crops, or any other property.

4) Backfilling shall be done with approved material after concrete or masonry is fully set. The backfilling is to be done upto the original surface in layers not exceeding 150 mm compacted thickness to be compacted with the help of suitable equipment such as trench compactor,

mechanical tamper, rammer plate vibrator etc.

5) The work shall be carried out as per Clause 304 of MORTH Specifications for Road and Bridge Works.

**e. Embankment and Subgrade Construction**

1) This work also involves construction of subgrades, earthen shoulders and miscellaneous backfills in addition to the construction of embankment for accommodating the roadway. The materials used for this work shall be soil, moorum, gravel, reclaimed material for pavement, fly ash, pond ash, a mixture of these. Materials from swamps, marshes and bogs, peat, logs stump, perishable material, any soil classified as OL, OI, OH or Pt, material susceptible to spontaneous combustion, materials in frozen condition, clay with liquid limit exceeding 50 and plasticity index exceeding 25 and materials with salts resulting in leaching in the embankment should be considered unsuitable material for embankment.

2) Permit delivery of embankment material to site only if the necessary rollers in working condition are present at site. Have a special check on the following points during the construction operations:

i) Before starting the construction operation, the site should be cleared and grubbed. The limits of the embankment/ sub-grade should be marked by fixing batter pegs on both sides at regular intervals. The embankment should be built sufficiently wider than the designed dimension so that surplus material may be trimmed.

ii) If the foundation of embankment is in area with stagnant water, the same should be removed by bailing out or pumping and should be kept dry. The drain water discharge should not cause damage to the works, crops, or any other property.

iii) All areas covered by embankment foundation shall be stripped to specified depths, not exceeding 150 mm, and stored in stockpiles of height not existing 2 m for covering embankment slopes.

iv) The soil delivered at site must be obtained from approved sources. The guidelines and environmental requirements, in respect of excavation and borrow areas as stipulated from time to time by MOEF and local bodies, are to be strictly followed by the Concessionaire.

v) Reserve better of the available fill material for the top 500 mm of the embankment and shoulders. If heavy clays have to be used, have these deposited in the bottom layers.

vi) Clods or hard lumps of earth should be broken down. The size of clods should not exceed 75 mm when placed in body of embankment and 50 cm when placed in subgrade portion.

vii) Static three wheeled roller, self-propelled single drum vibrator roller, tandem vibratory roller, pneumatic tyre roller pad foot roller etc. of suitable size and capacity shall be used for the different types and grades of materials required to be compacted either individually or in suitable combination.

viii) The embankment and subgrade material shall be spread in layers of uniform thickness over the entire width of embankment by a motor grader. The compacted thickness of each layer shall not be more than 250 mm. The compacted thickness of each layer shall not be more than 200 mm when static roller is used. Successive layers shall not be placed until the layer under construction has been thoroughly compacted to the specified requirements. Compacted layer shall be finished parallel to the final cross- section of the embankment.

ix) Subgrade can be made up of in-situ material, select soil, or stabilized soil forming the foundation for the pavement. It should be well compacted to derive optimal strength and to

limit the rutting caused due to additional densification of the layer during service life. When the subgrade is formed using a material which is stronger than the upper 500 mm of embankment soil or when the subgrade itself is prepared in two separate layers with significantly different strengths, the effective combined contribution of the subgrade and the embankment layers has to be considered for design. A sub grade CBR value of 8 % has been considered for the design of pavement. Sub grade is to be compacted with minimum of 98 % of maximum dry density of modified proctor compaction tests.

Table 2.2: Compaction requirement of Embankment and Subgrade

| Sr. No. | Type of work | Relative compaction as percentage of maximum laboratory dry density as per IS:2720 (Part 8) |
|---|---|---|
| **1** | Subgrade and earthen shoulders | Not less than 97% |
| **2** | Embankment | Not less than 95% |
| **3** | Expansive Clays | a) Subgrade and 500 mm portion just below the subgrade - -Not allowed<br>b) Remaining portion of embankment - 90-95% |

x) Moisture content of the soil shall be checked and corrected at the site of placement prior to commencement of compaction. If required, additional water should be sprinkled from a sprinkler capable of applying water with a controllable rate of the flow, without any flooding. The water shall be added uniformly and thoroughly mixed in soil by blades. If the material at site is too wet, it shall be dried by aeration and exposure to the sun till the moisture content is acceptable.

xi) The number of passes to achieve the desired compaction will depend on the nature of soil and type of compaction plant. Compaction trials are to be conducted to demonstrate the efficacy of the equipment to be used.

xii) Each layer should be rolled to the camber/cross fall of the road and this should be maintained so as to prevent ponding.

**3. Sub-Bases and Bases (Non-Bituminous)**

**A. Granular Sub-base**

1) The physical requirements of material for granular subbase should be as per indicated in Table 2.3. The construction operations of granular sub base shall be carried out as per clause 401 of MORTH Specifications for Road and Bridge Works.

Table 2.3: Physical requirements for Materials for Granular Sub-base

| **Material Property** | **IS Code** | **Value** |
|---|---|---|
| Aggregate Impact Value (AIV) | IS:2386 (Part 4) or IS:5640 | 40% maximum |
| Liquid Limit | IS:2720 (Part 5) | Maximum 25 |

| | | |
|---|---|---|
| Plasticity Index | IS:2720 (Part 5) | Maximum 6 |
| CBR at 98% dry density (at IS:2720-<br>Part 8) | IS:2720 (Part 5) | Minimum 30 unless otherwise specified in the Concession |

**B. Stabilized Soil Sub-base**

1) Mechanical Stabilization consists of blending the missing fraction (clay with sand and sand with clayey soils) for improving gradation and bringing the plasticity within permissible limits. Gradation, plasticity and density are important controls. Lime-soil stabilization is a process of stabilization of clayey soils by the chemical action of lime on the clay minerals and can be used as lower subbase or improved subgrade. The soil used for stabilization shall be local clayey soil having plasticity index greater than 8. The lime used for lime soil stabilization shall be commercial dry lime having a purity of not less than 70 per cent by weight of quick lime. It should be properly stored to avoid prolonged exposure to the atmosphere. The soil for lime soil stabilization shall be pulverized so that it passes 100 per cent through 26.5 mm IS Sieve and passes 80 per cent by weight through I.S. Sieve 5.6 mm. The material used for cement or cement fly ash treatment shall be soil including sand and gravel, laterite, kankar, brick aggregate, crushed rock or slag or any combination of these. It shall meet the specified grading and shall have uniformity co-efficient not less than 5. If the material passing 425-micron sieve is plastic, it shall have liquid limit not greater than 45 percent and plasticity index of not greater than 20 percent. The cement shall either be OPC, PPC, or Portland Slag cement. The fly ash shall meet the specified requirement. The mix design for cement stabilization should be done based on 7-day unconfined compressive strength (UCS) and/or durability test under 12 cycles of wet dry conditions. The laboratory strength values should be at least 1.5 times the minimum field UCS taken for the pavement design. The mix design shall be done to achieve a strength of 1.75 MPa on cylindrical specimen.

**C. Crushed cement concrete sub-base**

1) This work consists of breaking and crushing the damaged cement concrete slabs and recompacting the same as sub-base in one or more layers. The thickness of each layer shall not exceed 75 mm compacted thickness. Coarse aggregate shall be broken cement concrete slabs crushed to a size not exceeding 75 mm and conforming in the specified grading. The crushed material shall be spread on the prepared subgrade with the help of a motor grader with three wheeled power rollers of 80 to 100 kN capacity or tandem or vibrating rollers of 80 – 100 kN static weight. The work shall be carried out as per clause 405 of MORTH Specifications for Road and Bridge Works.

**D. Wet Mix Macadam (WMM)**

1) The work shall consist of laying and compacting clean, crushed, graded aggregate and granular material premixed with water, to a dense mass on a prepared subgrade/ sub base/base or existing pavement. The thickness of a single compacted WMM layer shall not be less than 75 mm. The compacted depth of a single layer of the subbase course may be upto 200 mm when vibrating or other approved types of compacting equipment are used. The aggregates shall conform to the physical requirements same as the WBM.

2) The construction operations shall be carried out as per clause 406 of MORTH Specifications for Road and Bridge Works. The mix should be prepared in approved mixing plant of suitable capacity having provision for controlled addition of water and forced/ positive mixing arrangement, like, pug mill or pan type mixer of concrete batching plant. The mixed material

should be uniformly wet, and no segregation should be permitted. The mix should be spread uniformly and evenly in required quantities on the prepared subgrade/sub-base/base by a self-propelled paver finisher. In no case should the mix be dumped in heaps on the area. In exceptional cases, if permitted, motor grader may be used.

3) After the mix has been laid to the required thickness, the rolling shall be uniformly compacted by a suitable roller. 80-100 KN smooth wheeled roller may be used for a compacted thickness of not exceeding 100 mm. For a compacted single layer upto 200 mm the compaction shall be done with a vibratory roller of minimum static weight of 80-100 KN. The roller speed should not exceed 5 km/hour. Rolling should continue till density achieved is at least 98 per cent maximum dry density for the material as per IS:2720 (Part 8). When irregularity develop during rolling which exceeds 12 mm with a 3 m straight edge, the surface should be loosened and premixed material added or removed as required before rolling again so as to achieve uniform surface. It is not advisable to lay the wet mix macadam during rains and the tempo of work suffers during rains. After final compaction of the WMM course, the road shall be allowed to dry for 24 hours.

**E. Crusher-run macadam base**

1) Crusher-run macadam base is constructed of materials obtained from crushed rock only, satisfying physical requirements indicated in Table 2.4. If crushed gravel/shingle is used, minimum 90 per cent pieces retained on 4.75 mm size sieve should have at least two fractured faces. The works are to be carried out as per clause 407 of MORTH Specifications for Road and Bridge Works.

Table 2.4: Physical requirements of coarse aggregates for Crusher-run Macadam base

| Sr. No. | Test | Test Method | Requirements |
|---|---|---|---|
| 1 | Los Angeles Abrasion Value | IS:2386 (Part 4) | 40 %(Max) |
| 2 | Aggregate Impact Value | IS:2386 (Part 4) or IS:5640 | 30 %(Max) |
| 3 | Combined Flakiness and Elongation Indices | IS:2386 (Part 1) | 35 %(Max) |
| 4 | Water absorption | IS:2386 (Part 3) | 2% (Max) |
| 5 | Liquid Limit of material passing 425 microns | IS:2720 (Part – 5) | 25 (Max) |
| 6 | Plasticity Index of material passing 425 microns. | IS:2720 (Part – 5) | 6 (Max) |

2) After the base course material has been deposited it shall be thoroughly blade mixed to full depth alternately from edges to center and back using water to moisten the materials sufficiently to prevent their segregation. Compaction may be done using 80 to 100 KN weight smooth wheel roller for single compacted thickness up to 100 mm. If vibratory roller of minimum 80 to 100 KN is used single layer up to 200 mm can be compacted. The speed of roller should not exceed 5 km/hour. Each layer shall be compacted to not less than 98 per cent of maximum density as per IS:2720.

## 4. Bitumen Bound Bases and Surfacing

### A. General Requirements

1) General requirements on materials, mixing, transporting, laying, compaction, joints and construction of bituminous pavement layers, protection of the environment etc. are laid down in Clause 501 of MORTH Specifications for Road and Bridge Works.

### B. Prime Coat

1) Prime coat consists of application a single coat of low viscosity liquid bituminous material to a porous granular surface preparatory to the superimposition of bituminous treatment or mix. The primer shall be cationic bitumen emulsion SS1 grade or medium curing cut back bitumen. This work is to be carried out as per clause 502 of MORTH Specifications for Road and Bridge Work. Bituminous primer should not be applied during a dust storm, when the weather is foggy or rainy or windy or when the temperature in the shade is less than 10°C. After the application of cut-back, the surface should be allowed to cure for at least 24 hours.

### C. Tack-Coat

1) The binder for tack coat should be either cationic bituminous emulsion (RS 1) or paving bitumen of VG-10 grades conforming to IS:73. Cut back bitumen RC 70 to be used restrictively for site at sub-zero temperature or for emergency application. The quantity of binder should be as per Table-2.5.

Table 2.5 - Rate of application of Tack Coat

| **Type of Surface** | **Rate of spray of binder in kg/sq.m** |
|---|---|
| Bituminous surface | 0.2-0.3 |
| Granular surface treated with primer | 0.25 – 0.30 |
| Cement Concrete pavement | 0.30 - 0.35 |

2) The binder should be applied uniformly with approved equipment capable of spraying bitumen at specified rate and temperature to provide a uniform unbroken spread of bitumen. The succeeding construction should be made only after curing the tack coat. The works are to be carried out as per clause 503 of MORTH Specifications for Road and Bridge Works.

### D. Dense Bituminous Macadam (DBM)

1) The work consists of the construction of a single layer of compacted crushed aggregates premixed with bituminous binder for use in base/binder and profile corrective course. The thickness of single layer shall be 50 mm to 100 mm. Job mix formula for DBM shall comply with Clause 505.3.3 of the MORTH Specifications. The bitumen shall be viscosity grade paving bitumen as per IS:73, modified bitumen conforming to IRC-SP:53 and IS:15462. Plant trials and laying trials are to be carried out as per clause 505 of MORTH Specifications for Road and Bridge Works. The construction operation for DBM including laying of and stress absorbing layer, should be in accordance with Clause 505.4 of the MORTH Specifications for Road and Bridge Works.

### E. Bituminous concrete (BC)

1) The work consists of construction of bituminous concrete for use in wearing and profile corrective courses. This work consists of construction in a single layer on previously prepared bituminous bound surface. A single layer shall be 30 mm/40 mm/50 mm thick. Mix design and

construction operations for bituminous concrete should conform to Clauses 507.3 and 507.4 of the MORTH Specifications for Road and Bridge Works respectively.

Table 2.6- Physical requirements for coarse aggregates for bituminous concrete

| Property | Test | Specification | Method of Test |
|---|---|---|---|
| Cleanliness (dust) | Grain size analysis | Max 5% passing 0.075 mm sieve | IS:2386 Part I |
| Particle shape | Combined Flakiness and Elongation Indices | Max 35% | IS:2386 Part I |
| Strength | Los Angeles Abrasion Value or Aggregate Impact Value | Max 30%<br>Max 24% | IS:2386 Part IV |
| Durability | Soundness either Sodium Sulphate or Magnesium Sulphate | Max 12%<br>Max 18% | IS:2386 Part V |
| Polishing | Polished Stone Value | Min 55 | BS:812-114 |
| Water Absorption | Water absorption | Max 2% | IS:2386 Part III |
| Stripping | Coating and Stripping of Bitumen Aggregate Mix | Minimum retained coating 95%* | IS:6241 |
| Water Sensitivity | Retained Tensile Strength | Min 80%* | AASHTO 283 |

1) The nominal maximum particle size is the largest specified sieve size up on which any of the aggregate is retained. ** Corresponds to specific gravity of aggregate being 2.7. In case aggregate have specific gravity more than 2.7, the minimum bitumen content can be reduced proportionately. Further the region where highest daily mean air temperature is 30°C or lower and lowest daily air temperature is – 10°C or lower, the bitumen content may be increased by 0.5 percent.

**F. Mastic asphalt**

1) This work shall consist of constructing a single layer of mastic asphalt wearing course for road pavements and bridge decks. This is not for the thin layer on bridge decks below a bituminous concrete layer. Mastic asphalt is composed of suitably graded mineral filler and coarse aggregates, fine aggregates and hard grade bitumen as to form a coherent, void less impermeable mass, solid or semi solid under normal temperature conditions but sufficiently fluid when brought to a suitable temperature to be spread by means of a float in manual construction and by paver in mechanized construction. The binder for the mastic asphalt shall be a industrial grade 85/25 bitumen.

**G. Reclamation, Recycling and Reprocessing of the Existing Pavement:**

The existing flexible Pavement shall be restored by a sustainable process and the existing pavement materials—primarily aggregates and bituminous binders shall be reclaimed and reused after undergoing reprocessing as per IRC 120 : 2015. This can be applied for resurfacing, repaving, or complete reconstruction, depending on the current condition of the pavement, the properties of the reclaimed materials, and the required treatment.

The pavement designs shall accommodate the specific characteristics of reclaimed materials utilizing appropriate methods, equipment, and quality control measures to efficiently reclaim and

reprocess materials. Design and technology shall be properly managed so that recycled pavements can deliver high performance in terms of strength, durability, and serviceability.

## 2.4 Paver Block

A. Scope - The paver blocks are proposed to be used for Pedestrian Ways, Paved shoulders and Footpaths. The interlocking paver block of 80 mm thickness to be used for pedestrian ways and footpaths.

B. Material - Bedding Sand Course: The bedding sand shall consist of a clean well graded sand passing through 4.75mm sieve and suitable for concrete. The bedding should be from either a single source or blended to achieve the following grading.

Table 2.7 Bedding and Jointing Sand Requirement

| **In Sieve size** | **% passing for bedding** | **% passing for jointing** |
|---|---|---|
| 9.52 | 100 | - |
| 4.75 | 95-100 | - |
| 2.36 | 80-100 | 100 |
| 1.18 | 60-100 | 90-100 |
| 600 micron | 25-60 | 60-90 |
| 300 micron | 10-30 | 30-60 |
| 150micron | 5-15 | 15-30 |
| 75 micron | 0-10 | 10-20 |

1) The Concessionaire shall be responsible for ensuring that single-sized, gap-graded sands or sand containing an excessive fines or plastic fines are not used. The sand particles should preferably be sharp not rounded as sharp sand possess higher strength and resist the migration of sand from under the block to less frequent areas even though sharp sands are relatively more difficult to compact than rounded sands, the use of sharp sands is preferred for the more heavily trafficked driveways. The sand use for bedding shall be free of any deleterious soluble salts or other contaminants likely to cause efflorescence.

2) The sand shall be of uniform moisture content and within 4% - 8% when spread and shall be protected against rain when stockpiled prior to spreading. Saturated sand shall not be used. The bedding sand shall be spread loose in a uniform layer as per drawing. The compacted uniform thickness shall be of 45mm and within +/- 5mm thickness variation shall not be used to correct irregularities in the base course surface.

3) The spread sand shall be carefully maintained in a loose dry condition and protected against pre-compaction both prior to and following screening. Any pre- compacted sand or screened sand left overnight shall be loosened before further laying of paving blocks take place.

4) Sand shall be slightly screened in a loose condition to the predetermined depth only slightly ahead of the laying of paving unit.

**C. Ready Mix Concrete**

1) The concrete mix design should be followed for each batch of materials separately and automatic batching plant is to be used to achieve uniformity in strength and quality.

2) The concrete pavers should have perpendiculars after release from the mould and the same should be retained until the laying. The surface should be of anti- skid and anti-glare type. The pave should have uniform chamfers to facilitate easy drainage of surface run off. The pavers should have uniform interlocking space of 2mm to 3mm to ensure compacted sand filling after vibration on the paver surface.

**D. Manufacturing & strength**

1) The pavers shall be manufactured in single layer only. Paver block machine should be used for manufacturing the blocks. The manufacturing of the paver block should meet the requirements as per IS: 15658-2006.

2) The average compressive strength of the 80mm thick paver blocks tested shall be 40 N/Sq. mm. as per the Table 3 Compressive Strength Requirements of Concrete Paver Blocks of IS 15658-2006.

**E. Laying & Interlocking**

1) Once the laying pattern has been established, it shall continue without interruption over the entire pavement surface. Cutting of blocks, the use of infill concrete or discontinuities in laying pattern is not permitted in other than approved locations.

2) Paver blocks shall be laced on the un-compacted screened sand bed to the nominated laying pattern, care being taken to maintain the specified bond throughout the job. The first row shall be located next to an edge restraint. Specially manufactured edge paving blocks are permitted, or edge blocks may be cut using a power saw, a mechanical or hydraulic guillotine, bolster or other approved cutting machine.

3) Paver blocks shall be placed to achieve gaps nominally 2 to 3 mm wide between adjacent paving joints. No joint shall be less than 1.5mm not more than 4mm. Frequent use of string lines shall be used to check alignment. In this regard, the "laying face" shall be checked at least every two metres as the face proceeds. Should the face become out of alignment, it must be corrected prior to initial compaction and before further laying job is proceeded with.

4) In each row, all full blocks shall be laid first. Closure blocks shall be cut and fitted subsequently. Such closer blocks shall consist of not less than 25% of a full block.

5) To infill spaced between 25mm and 50mm wide concrete having screened sand, coarse aggregate mix and strength of 40 N/Sq mm. shall be used. Within such mix the nominal aggregate size shall not exceed one-third the smallest dimension of the infill space. For smaller spaces dry packed mortars shall be used.

6) Except where it is necessary to correct any minor variations occurring in the laying bond, the paver blocks shall not be hammered into position.

7) Where adjustment of paver blocks necessary care shall be taken to avoid premature compaction of the sand bedding.

8) Initial Compaction: After laying the paver blocks, they shall be compacted to achieve consolidation of the sand bedding and brought to design levels and profiles by not less than Two passes of a suitable plate compactor or baby roller of suitable capacity.

9) The compactor shall be a high-frequency, low amplitude mechanical flat plate vibrator having plate area sufficient to cover a minimum of twelve paving blocks. Prior to compaction all debris shall be removed from the surface compaction shall proceed as closely as possible following

laying and prior to any traffic. Compaction shall not, however, be attempted within one meter of the laying face. Compaction shall continue until lipping has been eliminated between adjoining blocks. Joints shall then be filled and recompacted.

10) All work further than one meter from the laying face shall be left fully compacted at the completion of each day's laying.

11) Any blocks that are structurally damaged prior to or during compaction shall be immediately removed and replaced.

12) Sufficient plate compactors shall be maintained at the paving site for both bedding compaction and joint filling.

13) Joint Filling and Final Compaction: As soon as possible after compaction and in any case prior to the termination of work on that day and prior to the acceptance of vehicular traffic, sand for joint filling shall be spread over the pavement.

14) Joint sand shall pass a 2.36mm (No.8) sieve and shall be free of soluble salts or contaminants likely to cause efflorescence. The same shall comply with the following grading limits.

**F. Sand for bedding**

1) The Concessionaire shall supply a sample of the jointing sand to be used in the Concession prior to delivering any such materials to site for incorporation into the works. Certificates of test results issued by a recognized testing laboratory confirming that the samples conform to the requirements of these specifications shall accompany the sample.

2) The jointing sand shall be boomed top fill the joints. Excess sand shall then be removed from the pavement surface and the jointing sand shall be compacted with not less than one (1) Pass by the plate vibrator and joints refilled with sand to full depth. This procedure shall be repeated until all joints are completely filled with sand. No traffic shall be permitted to use the pavement until all joints have been completely filled with sand and compacted.

3) Both the sand and paver blocks shall be dry when sand is spread and broomed into the joints to prevent premature setting of the sand.

4) The difference in level (lipping) between adjacent blocks shall not exceed 3mm with not more than 1 % in any 3m x 3m area exceeding 2mm. pavement which is deformed beyond above limits after final compaction shall be taken out and reconstructed to the satisfaction of the Independent Engineer.

**G. Edge Restraint:**

1) Edge restrains need to be sufficiently robust to withstand override by the anticipated traffic, to withstand thermal expansion and to prevent loss of the laying course material from beneath the surface course. The edge restraint should present a vertical face down to the level of the underside of the laying course. The surface course should not be vibrated until the edge restraint, together with any bedding or concrete launching, has gained sufficient strength. It is essential that edge restraints are adequately secured.

## Section 3

## TBM Tunnel

### 3.1 INTRODUCTION

This section specifies design standards, materials, methods and workmanship required for the design and construction of TBM bored tunnels, and other related underground structures.

### 3.2 Design consideration for TBM Bored tunnel

#### 3.2.1 Method Statement

1) The Concessionaire shall prepare and submit to the Independent Engineer for his consent, a detailed design report including calculations, schedules and drawings for tunnel construction, prior to the commencement of such works. Additional information shall be supplied upon request of the Independent Engineer. The Report shall explain the basis of the design, design assumptions, and design parameters of all civil and structural works to be undertaken.

2) The Concessionaire shall prepare a method statement presenting full details of the design, the materials, equipment, plant and operations involved in the construction of bored and submit to the Independent Engineer as part of the Design Report. The Concessionaire shall ensure that ground movements and changes to the piezometric pressure which may affect adjacent roadway tracks, subway, utility services and any adjacent buildings, surface or underground structures are kept to a minimum.

#### 3.2.2 Types and General Methods of Analyses

1) The tunnel finish size and horizontal alignment shall be as per Schedule B of the contract. However Concessionaire can make improvement to the alignment, but he must demonstrate that designed alignment comply with good design practice and the alignment requirement of the Design Criteria. The deign alignment shall be approved by the Authority subject to condition that there is extra time or cost is involved due to changes.

2) The Concessionaire shall be always responsible for the safety and security of excavations during the execution of the Contract. The Concessionaire shall present to the Independent Engineer details of his proposed methods for excavation, and spoil Disposal removal. No excavation shall take place until the Authority Representative's consent has been obtained.

3) Excavation shall be carried out in a uniform and controlled manner; over-cutting shall be kept to a minimum. In water-bearing strata the Concessionaire shall use such methods and take such steps as are necessary to control flows and maintains the stability of the excavation.

4) Where the Contract specifies limits to surface settlement and/or protection in respect of existing service or structures, the Concessionaire shall provide calculations demonstrating that the method of excavation will result in compliance with those requirements. Details of the monitoring arrangements that are proposed for the recording of movements and the verification of the degree of any settlement or damage to services or structures shall be in accordance with Standard.

5) Bored tunnel for the Road Corridor will be in rock and soil and will be excavated using tunnel boring machines. Initial tunnel support will generally include precast concrete segments, shotcrete/wire mesh, rock bolts, lattice girders, steel sets, or forepoles wherever necessary.

6) Geometries and stability of rock wedges affecting tunnel support requirements, including completely /highly weathered rock with controlling remnant rock jointing or other structure, shall be determined analytically, generally using stereographic projection, finite element method or vector methods. Analyses shall consider planar sliding along individual joints and block sliding, or fallout, along joint-set combinations. Analyses shall provide for both static and dynamic loading conditions.

### 3.2.3 Design Method

1) The method of analysis of the permanent lining shall take into account the proximity to the face at the time of installation and the potential for additional ground loads as the face advances.

2) The design method for the analysis of the bored tunnel linings shall take into account the interaction between the lining and the ground, the deflection of the lining and the redistribution of the loading dependent upon the relative flexibility of the lining, the variability and compressibility of the ground. The method of analysis shall conform Compressibility of the ground, durability aspects that shall include impermeability, electrical resistivity of concrete, ASR resistance and sulphate resistance as per the guidelines of the International standards.

3) Permanent lining design shall consider all loads as described in subsequent section and any additional ground loads from time-dependent ground strains. If the life of the temporary lining is less than the design life for the Project, then the Concessionaire shall design the secondary lining ignoring the contribution of the temporary support for structural purposes.

4) Due account shall be taken of the degree of flexibility of the linings to be used in the various soil conditions and taking account of the size, proximity, timing and method of construction of adjacent excavations. The inherent lining flexibility may have to be reduced in order to maintain acceptable values for the deflection of the lining.

5) The Concessionaire shall at his own expense conduct soil investigations where his designs or method statements identify that it is necessary or prudent to do so to enable him to identify all foreseeable circumstances which may affect the execution of the works and to ensure that there is no likelihood of meeting unexpected conditions of a critical nature.

6) If the Concessionaire intends to carry out additional ground investigation from the surface, beyond the limits of the worksite, he shall make his own arrangements with landowners and occupiers for the necessary access. He shall not assume that such access will necessarily be granted, although the Authority will provide assistance where it appears that this would be beneficial.

7) If surface access for ground investigation is not available, or if for any other reason there is a significant likelihood of encountering geological hazards whose location is unknown, the Concessionaire shall identify in his method statements the means by which such hazards will be found as construction proceeds. The Concessionaire shall also identify how his tunnel design and construction activities will be modified to recognise the deficiency of ground information prior to tunnel driving.

8) During tunnel driving ground investigation data shall be kept under constant review and reinterpreted as more detailed information becomes available, to maintain up to date predictions of the ground likely to be encountered. This review shall be fully integrated into the construction risk control and management systems and should typically include:

    a) detailed geological logging of the ground exposed during construction

    b) probing ahead of and around the tunnel face, if the ground changes or expected to change.

    c) interpretation of fresh data and correlation with previous information

    d) prediction of ground conditions likely to be encountered.

9) Ground information from all construction activities shall be collated and interpreted.

10) The geotechnical design parameters adopted and the method of analysis of the lining shall be subject to the consent of the Authority prior to commencement of design.

11) The design life required shall be obtained by the use of durable materials, corrosion protection, resistance to or avoidance of wear etc. All underground works shall be designed to achieve the

following minimum design lives with minimum maintenance

| | |
|---|---|
| (a) Main structure resisting ground and groundwater loads | 100 years |
| (b) Non-structural components | 50 years |
| The design Fire Resistance Period shall be 4 hours. | |

12) The Concessionaire shall design all necessary linings for the tunnel and shafts including temporary linings. If any proprietary methods, materials or components are proposed to be used the Concessionaire shall be responsible for demonstrating their fitness for purpose to the full satisfaction of the Authority.

13) The Concessionaire shall determine the configuration of rings, segmentation and details of joints and fixings etc. to suit ground conditions, loadings, methods of construction and all functions in the complete Works as described herein. The design shall address aspects including the following, as appropriate:

    a. Ring configurations,

    b. segment size and form,

    c. Fixing details including:

    d. ring to ring fixings,

    e. segment to segment fixings,

    f. For fixing all equipment's to be installed under this Contract.

    g. for fixing equipment required by Interfacing Concessionaires/Concessionaires etc. to suit segment position,

    h. handling and installation.

    i. Holes, recesses, and fixtures for other system components

    j. Designs shall allow for tolerance in production and installation of segments.

    k. Other components:

    l. grout Hole Valves,

    m. gaskets,

    n. bedding and packing materials.

14) Instrumentation and monitoring to demonstrate performance of the installed linings.

15) The Concessionaire shall submit for the consent of the Authority a comprehensive schedule of tests to establish the quality and performance of all elements of the tunnel lining, including:

    a. segment materials,

    b. permeability,

    c. production tolerances,

    d. joint performance and load capacity including effect of joint misalignment and birds

mouthing with aligned and misaligned joints,

e. performance of joint bedding/packing materials,

f. lateral bending tests to demonstrate resistance to jacking forces,

g. gasket performance with aligned/misaligned joints,

h. self-sealing grout hole,

i. capacity of all fixings.

### 3.2.4 Loads

a) The method of analysis shall consider in situ ground stresses and shall provide evidence and/or measurements to the Authority in support of the parameters adopted in the design.

b) Analysis shall be undertaken of the additional ground loadings imposed by adjacent structures on the underground structures and due account taken of the additional stresses in the design of the underground structures.

c) Where the tunnel is adjacent to buildings and other structures, analysis shall be provided to ensure that no loss of support can occur which endangers the stability of the buildings and structures and that settlement will be within standard specified limits.

d) All tunnel sections shall have permanent, durable, structural linings, generally consisting of bolted steel segments, pre-cast concrete segments, or cast-in-situ, plain or reinforced concrete.

e) Linings shall be designed to withstand all environmental loadings and effects without detriment. In general, tunnel linings shall be designed to fulfil the following requirements and to resist the following loadings.

*(i)* Superimposed surface loads from traffic, existing structures over and adjacent to the tunnel, and any specified future loads.

*(ii)* Soil/rock, water, and seismic loads.

*(iii)* Roadway loads.

*(iv)* Structural requirements for resisting buckling.

*(v)* Long- and short-term ground yield or squeeze.

*(vi)* Unequal grouting pressures.

*(vii)* Adjacent tunnelling or excavation.

*(viii)* Openings in, or extensions to, the lining.

*(ix)* Long- or short-term loads induced by construction.

*(x)* Temperature Rise/Fall and shrinkage.

*(xi)* Handling loads, including impact, especially in the case of unreinforced segments.

*(xii)* Jacking forces, where appropriate.

### 3.2.5 Loading Conditions

a) The design of the linings for the tunnel shall be fully compatible with the Concessionaire's proposed method of construction. The principal method is expected to be shield driven tunnel (TBM) with permanent precast concrete lining.

b) The design shall also take into account all loadings, the requirements of the overall schedule, the need

for further investigations as necessary, and contract limitations with regard to ground movements and de-watering.

c) The tunnel alignment shall generally follow the alignment shown on the Tender Drawings

d) All components of underground structures shall be proportioned to withstand the applied loads and forces as follows:

i. Dead load comprises the self-weight of the basic structure and secondary elements supported and the weight of earth cover. The depth of cover shall be the actual depth or as per Concessionaire safe design assumption. The maximum depth to tunnel axis shall be used.

ii. Traffic surcharge shall be equivalent to Class AA/70R loading of IRC 6.

iii. Loads from existing or known future adjacent structures above or within the area of influence, which will remain in place above the tunnel, or any specified future loading. The applicable foundation load shall be computed based on the height and type of occupancy or use. For known future small buildings, a minimum load based on a dead and live load of 50 kPa (up to 2 storey)/110Kpa (3 to 7 storey) at the foundations shall be used.

iv. Additional support, ground treatment or additional lining thickening shall be provided unless it can be shown that adequate provision already exists.

v. Where provision for a specific future structure is not made a minimum surcharge of 50 kPa at the existing or design ground level.

vi. Hydrostatic pressures ignoring pore pressure relief obtained by any seepage into the tunnel. Two ground water levels shall be considered.

a. Normal

b. One metre above 20-year Flood level or 1.5m above known HFL

e) Loads and load changes due to known construction activity in the vicinity of the tunnel, such as the excavation of underpasses, basements, pile groups, bridges, diaphragm walls and cable ground anchors.

f) The design of the tunnel linings shall take into account the proximity of the tunnel one to another, the sequence and timing of construction and the proximity of adjacent structures and utility services.

### 3.2.6 Flotation

a) For floatation check, the water table is assumes to coincide with the Ground level.

b) Where the bored tunnel is relatively shallow they shall be checked for the possibility of flotation due to differential water pressure at representative typical locations.

c) The overall FOS (factor of safety) against flotation of 1.1 shall be considered in detailed design. A load factor of 0.9 shall be applied to resisting loads such as self-weight of the structure, weight of overburden/ backfill material over the structure.

d) The Concessionaire shall include in the design of the bored tunnel structures suitable methods for countering the uplift due to displaced water.

### 3.2.7 Crack Width

a) All structural concrete elements shall be designed to prevent excessive cracking due to flexure, early & long-term age thermal shrinkage. Flexural crack width shall be checked in accordance with Appendix F of IS: 456. The limits specified in Cl. 35.3.2 of IS:456 has to be followed.

b) For members exposed to earth/ground and ground water (tunnel support), the maximum design crack

width shall not exceed 0.2 mm irrespective of whether any additional protections, such as waterproofing membrane, are provided to the members at the exposed face (ground face) of the structure. However for the non-ground face (intrados of support) of the members, the maximum deign crack width shall not exceed 0.3mm.

### 3.2.8 Heave and Settlement

a) All tunnel designs shall be checked against flotation and heave in accordance with the methods specified above. Wherever these checks indicate a critical case the Concessionaire, at shall carry out a more rigorous analysis. Such analysis shall clearly show the factor of safety achieved by the design and shall be to the consent of the Authority.

### 3.2.9 Tunnel Lining

a) The permanent tunnel linings shall be bolted segmental precast concrete, except in case of cross-passages, enlargement of tunnel and bored tunnel where cast-in-situ lining shall be used.

b) Alternative types of lining may be proposed subject to the consent of the Independent Engineer.

c) The Concessionaire shall take into account, inter alia, the following when considering the design of lining:

*(i)* The internal diameter shall take account of the need to accommodate the Road Traffic requirement, Ventilation duct including Traffic signage and E&M fitting to be provided by the E&M Concessionaire.

*(ii)* Due allowance for relative movement between tunnels as described in Subsection 4.11.

*(iii)* The stiffness of the lining shall be sufficient to limit the maximum allowable deflection to on radius to 25mm. The distortional loads adopted shall also take account of the speed of reloading of the horizontal and vertical ground pressure and in the case of the shallow tunnel, the ability of the ground above the tunnel to generate sufficient passive resistance to maintain stability of the lining.

*(iv)* Stresses induced by grouting.

*(v)* The reinforcement for segmental concrete lining shall be detailed such that no electrical continuity will exist across the circle joints. To prevent the stray current effects and to inhibit the corrosion, Micro silica shall be added into concrete. Such concrete shall be tested in accordance with ASTM C 1202 and DIN 1048. RCPT value shall not exceed 1000 coulombs and water permeability shall not be more than 10 mm. However, reinforcement for in situ concrete lining or other structures shall be bonded to mitigate stray currents. Similarly, SGI lining segments shall be bonded to mitigate stray current effects. The bonding will be part of the corrosion control system to be installed by the Concessionaire. The corrosion control system shall be designed and installed by the Concessionaire with the Independent Engineer's consent. The system shall be tested to demonstrate its proper function.

*(vi)* Blind holes and other fixings shall be necessary for the installation of internal construction, brackets and equipment, such holes or fixings shall be detailed such that they have no adverse effect on the integrity, water tightness or design life of the linings.

### 3.2.10 Segmental Linings

a) The Concessionaire shall take into account, inter alia, the following when considering the design of linings:

*(i)* a segment shall be considered as a short column subjected to axial load and bending moment. The design of the segments shall be adequate for all temporary loads during stacking, lifting, erection and impact.

*(ii)* the width of segments shall suit the method of construction and shall not be so large that part shoving of the shield becomes a general necessity.

*(iii)* the width of segments shall be consistent with the capacity of the circle bolting arrangements to withstand the shear forces induced in linings built with staggered joints.

*(iv)* the lengths of segments shall be chosen with regard to bending stresses during handling and erection and the long-term stresses due to deflection and thrust. In the design for handling and erection a safety factor of 5.0 shall be applied to the self- weight of the segment combined with zero axial load.

*(v)* Opening of longitudinal joints.

*(vi)* The design of linings shall include suitable taper rings in order to negotiate the alignment curvature and to correct for line and level during construction with the minimum use of circumferential joint packers consistent with attaining the required degree of water tightness of the tunnel.

*(vii)* Drilling for fixing at pre-determined points on the lining may be permitted.

### 3.2.11 Segment Details

1) Gasket grooves - Gasket grooves shall be provided around all joint faces of each segment and key in accordance with the dimensions as approved by the Authority. The design shall incorporate sealing gaskets in the segmental design.

2) Concrete cover - Where reinforcement is incorporated into the segments the minimum cover to all reinforcement, including link steel, shall be provided as 50mm on all sides, except only at bolt holes where reduced cover of 25mm is acceptable provided a plastic sheath is provided

3) Grout holes - Grout holes shall be provided in segment as per design excluding the key and shall be of a nominal 50 mm diameter.

4) Mould for segment - All Moulds for casting segment should be new fabricated material with prior approval from Authority/Independent Engineer.

### 3.2.12 Tunnel Boring Machine (TBM) and Shields

1) The Concessionaire shall be fully responsible for the selection, design and supply of tunnelling machines, shields and backup equipment. The TBM shall also meet all the requirements as specified in Authority Requirements and Outline Construction Specification.

2) Tunnelling machines shall be robust with adequate safety margins for the anticipated duty, designed and manufactured to comply with all safety standards.

3) The Concessionaire shall submit to the Authority for his consent, a programme for the provision, factory inspection, testing, transport, erection and commissioning of TBM or shield. The Authority's consent does not, however, absolve the Concessionaire of his responsibility to use appropriate equipment and complete the work as scheduled.

4) Tunnelling Machines shall be assembled at the manufacturer's works Shops/ Concessionaire's facilities at site on completion of fabrication or modification and tested to demonstrate that all components operate correctly before the Authority or his authorised representative. Test running will also be required at site following assembly, prior to commencement of tunnel driving.

5) The Concessionaire shall ensure that all key personnel who are responsible for the driving, maintenance and control of the machine have received the necessary training in the duties that they are required to perform. Such training shall include emergency procedures.

6) The Concessionaire shall provide and maintain a complete list of the names of persons and their

duties, responsible for the operation of the machine, who have completed the appropriate training to an accepted standard. A Certificate of Competence shall be provided by the Concessionaire.

### 3.2.13 Waterproofing

1) During construction in water bearing ground, the seepage water shall be controlled by suitable means and design should provide for the same. The Concessionaire shall obtain the Authority's prior agreement to the process he intends to adopt. Pumping of large quantities of water such that the piezometric pressure in the vicinity is within permissible safe limits and Concessionaire is required to get permission from related authority.
2) Groundwater leakage rates shall not exceed 0.1 litre/m2/day and 0.2 litres/m2/day for segmental lining and in-situ lining respectively. For any 10m length of tunnel the water ingress rate shall not exceed 0.2 litre/m2/day and 0.4 litres/m2/day for segmental lining and in- situ lining respectively.
3) The design shall incorporate two sealing gaskets in the segment design. Materials for sealing gaskets shall be one gasket of hydrophilic material and one gasket of elastomeric type.
4) Materials shall have acceptable fire performance for use on an underground roadway.
5) Notwithstanding the above limits on groundwater leakage rates, the design shall aim to ensure that no loss of ground occurs through any part of the structure. All grouting holes shall be fitted with non-return valves with double sealing rings.

### 3.2.14 Underpinning of Existing Structures

1) Where the construction of tunnel or other underground works would necessitate removal of existing support or foundations to existing structures the Concessionaire shall carry out investigations of the extent of the existing works, their design and loading conditions. The Concessionaire shall design and carry out such works as are necessary to maintain the integrity of the structure at all times including its design life. No work shall commence prior to the consent of the Independent Engineer being given. Cost of design and provision of any support/strengthening of such structures will be deemed as included in the Concessionaire's Price.

### 3.2.15 Cross Passages

1) Passenger emergency evacuation design for cross passages between running tunnels which are constructed by bored method shall be in accordance with the requirement relevant IRC SP91 specifications.
2) The locations of cross passages should be as per IRC guideline, wherever possible, shall be chosen to avoid critical sections of the alignment where their construction could have an adverse effect on adjacent structures.

### 3.2.16 Sumps in Running Tunnel

1) Sumps shall be located at every low point within each running tunnel.
2) Wherever practicable the vertical alignment shall be chosen such that the locations of sumps avoid critical sections where their construction could have an adverse effect on adjacent structures.
3) The size of each sump shall take account of the anticipated rate of flow into the sump, the priority rating, the number and types of pumps to be installed and the reserve capacity required above alarm level.
4) The reserve capacity of a groundwater seepage sump shall be calculated on the basis of the area of tunnel lining applicable to the sump in accordance with the following formula.

$$VR = A * v * t * F.O.S. *10\text{-}3$$

Where,

VR = Volume of reserve, m3

A = Tunnel lining area, m2

v = Maximum leakage rate, l/m2/day

t = Maximum response time, (day)

F.O. S = Factor of Safety

5) For running tunnel low point sumps, the response time "t" shall be 24 hours and the factor of safety shall be 1.5.

6) The sump design shall include outlets for the longitudinal drainpipe and discharge mains, pumps of suitable capacity and power connection. Sumps shall be fitted with steel covers and provided with step irons or access ladder as approved. Permanent discharge mains shall be installed as well as embedment of conduits for permanent electric power cables to the pumps.

7) The linings of the sumps shall be designed for the appropriate ground and groundwater loads.

8) The design and construction of the junctions with the running tunnel linings shall be in accordance with the general requirements of these Outline Design Specifications.

### 3.2.17 Ground Treatment and Temporary Support

1) For all bored-tunnel sections, a plan shall be prepared, based on all of the available data, of the anticipated need for and methods of providing the following.

*(i)* Ground treatment at break-in / break-out locations

*(ii)* Ground treatment in advance of the tunnel excavation.

*(iii)* Temporary support during tunnel excavation.

2) This information and the assumptions on which it is based shall be shown on the design drawings. The effect of tunnelling activities on structures located above the line of the tunnel shall be determined and any remedial action necessary to minimize the settlement of these structures shall be implemented prior to tunnel excavation.

3) Detailed materials and workmanship specifications shall be provided for the use, if any, of shotcrete, or rock bolts, or both as part of any final/permanent liner or support system for tunnel.

### 3.2.18 Underpinning of Existing Building Structures (EBS)

1) Where the construction of bored tunnels or other underground works necessitates the removal of existing support or foundations to existing buildings, structures, utilities, services, wells, pavements, road furniture and the like (collectively termed EBS) the Concessionaire shall carry out investigations on the extent of the existing works, their design and loading conditions.

2) The Concessionaire shall design and carry out such works as are necessary to always maintain the integrity of the EBS including their entire design life, at no extra cost (no extra payment to the Concessionaire) to the Authority. No work shall commence prior to the Notice of No Objection of the Independent Engineer being given. Cost of design and provision of any support/strengthening of such structures will be deemed as included in the Concessionaire's Contract Price.

### 3.2.19 Ground Movements

1) The design of all Temporary and Permanent Works shall limit ground movement and distortions around the site and to avoid damage to adjacent EBS.

2) The Concessionaire shall carry out a risk assessment for all EBS within the influence zone of the Works. The analysis for the Temporary Works shall be properly related to the conclusions of this risk assessment.

### 3.2.20 Construction Dewatering

1) Temporary dewatering of construction excavations will be required to provide an undisturbed, stable and dry subgrade to permit construction and backfilling of the Permanent Works under dry conditions.

2) In general, the groundwater within the excavations shall be maintained at a level that permits achievement of the above and avoids heave, piping or base failure of the excavation.

3) Temporary dewatering methods (including recharging methods, if required) and system operations, along with other required temporary works, shall not lower the groundwater outside the walls supporting the excavations, nor result in undue settlement, distortion or loss of ground at adjacent EBS. In this respect, all the provisions/stipulations of the Contract pertaining to the permissible limits of groundwater table drawdown and protection of EBS (limits of EBS damage) shall be fully complied with.

4) The Concessionaire shall prepare and submit his design of his construction dewatering system (including recharging system, if required) to the Authority/ Independent Engineer for his Notice of No Objection. The construction dewatering design shall include determination of subsurface conditions and geotechnical design parameters, analysis to establish feasible methods, and system definition in sufficient detail to demonstrate that the general objectives can be achieved without adverse effect on adjacent EBS. The selected system shall generally provide for continuous (24-hour per-day) operation, adequate reserve equipment, and standby power.

### 3.2.21 Ground Improvement

1) Ground-improvement may be required along certain alignment segments of the Contract to control ground and EBS movement and distortion that may be induced by excavation and tunnelling and at tunnel break-in/break-out locations, in advance of bored tunnel excavation.

2) The Concessionaire shall prepare and submit his designs and method statements supported by analysis for all ground improvement to the Independent Engineer for his Notice of No Objection. These designs shall define performance objectives for the ground improvement

3) The information and assumptions on which the ground improvement is based shall be shown on the design drawings.

## 3.3 Instrumentation

1) The Concessionaire shall instrument, monitor and report on ground and EBS movement and distortion, groundwater level, stress and displacement in the excavation and lateral support system, structural movement during construction to check his predictions

2) Monitoring shall be carried out on a case-by-case day-to-day or more frequent basis depending upon the importance of EBS and/or the risk of damage to that EBS. Special attention shall be paid to the historical buildings and wells located along the alignment.

3) Monitoring shall begin prior to commencement of the Works to enable instrument base-line values to be determined accurately and shall continue until all movements and distortions to the ground and EBS, and changes to the groundwater table that might be attributed to the Works, as shown by the monitoring, have effectively ceased for a period of three months.

4) The Concessionaire shall submit a complete comprehensive instrumentation, monitoring and reporting scheme with his Design and prior to any construction which is designed to achieve the

following.

*(i)* To establish typical background movement, distortion, groundwater fluctuation, and noise and vibration limits for the ground, groundwater and EBS prior to commencement of the Works.

*(ii)* Protection to all parties during and after the construction by providing early warning of any excessive and undue movement and distortion of the adjacent ground and EBS.

*(iii)* To provide movement and deformation information for design verification of the Temporary and Permanent Works.

*(iv)* To ensure that the maximum allowable tolerances associated with various structures/elements within the zone of influence of the Works are not exceeded.

*(v)* To confirm that groundwater drawdown outside of the excavations does not exceed the expected fluctuation limits

5) Vibration recording devices shall be provided to monitor for vibrations which may cause damage to the proposed constructions and EBS. These devices shall be installed at intervals and locations to provide comprehensive coverage of the Works. Unless otherwise directed by the Fire/Life Safety Committee, these devices shall record ground accelerations generated by the Works to ensure that these accelerations do not exceed the values set by the relevant Authorities or those determined by the Concessionaire for the stability and safety of the Temporary and Permanent Works and adjacent EBS.

6) **Limiting Construction-Induced Vibrations at adjacent EBS**

In the design, the effects of construction-related vibrations shall be considered. Unless otherwise accepted by the applicable government agencies and the Independent Engineer peak particle velocities at adjacent EBS shall not exceed the values in the Table below (as per AASHTHO -1990 & DIN 4150 -3,1999):

7) Peal **Particle Velocities in mm/sec (max. Allowable) at adjacent EBS**

| **Existing Adjacent Structures** | **Peak Particle Velocities in mm/sec (Max. allowable)** |
|---|---|
| Most structures in “good” condition | 25 |
| Most structures in “fair” condition | 12 |
| Most structures in “poor” condition | 5 |
| Water-supply structures | 5 |
| Heritage structures/bridge structures | 5 |

8) Above limits are maximum permissible, however this may have to be restricted further if required to avoid damage to the adjacent EBS or causing discomfort to the occupants. Along the proposed alignment, other limitations may be imposed at adjacent EBS, such as hospitals, school buildings, telephone-exchange structures, special water- supply structures and Heritage structures etc. In addition, working hours for such equipment’s causing vibrations may have to be restricted, keeping the convenience and comfort of the occupants in mind

9) **EBS Protection**

a) The Concessionaire shall minimize the induced loads, and total and differential deflections (angular distortion) of the ground surface and EBS above or below the ground surface that may result from the Works. The impacts of construction shall be so limited as to not affect the operation of the EBS, road and pavement.

b) "Green-field" condition shall be considered in determining the total and differential deflections of the ground and EBS.

**10) Instrumentation, Monitoring and Reporting.**

**a)** The Concessionaire shall instrument, monitor, and report on ground and EBS movements and distortions, groundwater levels, stresses and displacements in the excavation and lateral support systems, structural movements during construction to validate and check his predictions.

**b)** Instrumentation and monitoring arrangements for ground and existing building structures (EBS) movement and distortion and changes to ground water table(s) and the trigger (Alert, Action and Alarm) levels for each and every identified EBS to be performed. Designer has to specify the required instrumentation and monitoring arrangement to maintain the saftey of the EBS.

**c)** Monitoring shall be carried out on a case-by-case day-to-day or more frequent basis depending upon the importance of EBS and/or the risk of damage to that EBS.

**d)** Special attention shall be paid to the heritage/historical buildings, sensitive structures and wells located along the alignment.

**e)** Monitoring shall begin prior to commencement of the Works to enable instrument base-line values to be determined accurately and shall continue until all movements and distortions to the ground and EBS, and changes to the groundwater table that might be attributed to the Works, as shown by the monitoring, have effectively ceased for a period of three months.

**f)** The Concessionaire shall submit a complete comprehensive instrumentation, monitoring and reporting scheme with his Design and prior to any construction which is designed to achieve the following.

*(i)* To establish typical background movement, distortion, groundwater fluctuation, and noise and vibration limits for the ground, groundwater and EBS prior to commencement of the Works.

*(ii)* Protection to all parties during and after the construction by providing early warning of any excessive and undue movement and distortion of the adjacent ground and EBS.

*(iii)* To provide movement and deformation information for design verification of the Temporary and Permanent Works.

*(iv)* To ensure that the maximum allowable tolerances associated with various structures/elements within the zone of influence of the Works are not exceeded.

*(v)* To confirm that groundwater drawdown outside of the excavations does not exceed the expected fluctuation limits

**g)** Vibration recording devices shall be provided to monitor for vibrations which may cause damage to the proposed constructions and EBS. These devices shall be installed at intervals and locations to provide comprehensive coverage of the Works. Unless otherwise directed by the Relevant Fire/Life Safety/any other Agencies/Authorities, these devices shall record ground accelerations generated by the Works to ensure that these accelerations do not exceed the values set by the Relevant Authorities or those determined by the Concessionaire for the stability and safety of the Temporary and Permanent Works and adjacent EBS.

The standard vibration limits for different types of structures located above or near tunnel construction sites, particularly during tunnel excavation using TBM, NATM, or cut-and-cover methods. These values are derived from national and international guidelines including Indian Railways, ISO 4866, and German DIN 4150-3 standards, which are often referred to in Indian urban tunneling projects:

**Vibration Limits for Structures Above Tunnel – Indian Context**

| Structure Type | Description | Peak Particle Velocity (PPV) Limit | Reference Standards |
|---|---|---|---|
| **Heritage Structures / Ancient Monuments** | Buildings of historical importance or fragile architecture | ≤ 2 mm/s | DIN 4150-3 (Category 1), ASI Guidelines |
| **Residential Buildings (Good Condition)** | Brick masonry or RCC frame structures used for housing | ≤ 5 mm/s | DIN 4150-3 (Category 2), IS 14894 |
| **Commercial / Public Buildings** | RCC structures, multi-story buildings with high occupancy | ≤ 8–10 mm/s | DIN 4150-3 (Category 3), Indian Railways |
| **Industrial Buildings** | Heavy RCC or steel-framed structures | ≤ 10–15 mm/s | DIN 4150-3, BS 7385 |
| **Critical Infrastructure** | Hospitals, data centers, laboratories, schools, etc. | ≤ 5 mm/s | IRC-SP:91-2019, ISO 4866 |
| **Underground Utilities (Pipelines, Sewers)** | Near tunnel alignment zone (usually <10m) | ≤ 3 mm/s | Project-specific safety limits |
| **Railway Tracks / Metro Corridors** | Existing tracks or operational tunnels nearby | ≤ 5 mm/s | Indian Railways Manuals, DMRC Specs |

**Notes:**

- PPV values are measured in millimeters per second (mm/s) and represent the peak vibration speed in any of the three axes (x, y, z).
- These limits should be verified through baseline structural condition surveys and continuous vibration monitoring.
- The limits may be lowered in case of weak soil strata, shallow foundations, or differential settlement risk.
- In India, project-specific limits are often finalized based on geotechnical study, structural audit, and

IE/PMC recommendation.

- Monitoring should be carried out using geophones or accelerometers placed at strategic points, linked to a data logger with alert thresholds.

**h) Additional Requirements for NATM Works**

The Concessionaire shall submit a complete comprehensive instrumentation, monitoring and reporting scheme with his Design and prior to any construction which is designed to achieve the following:

i) Safety during and after the construction by providing early warning of any excessive and undue ground movement inside the tunnel.

ii) To provide deformations and loading data for the verification of initial design of the initial and final support of the tunnel.

iii) To provide information about tunnel behaviour in order to optimize excavation and support activities during construction

**i)** Special requirements:

*(i)* The instruments shall be installed at locations and in accordance with a time schedule as per approved scheme or at vulnerable locations encountered during excavation.

*(ii)* Geotechnical instrumentation and the monitoring program may be subject to alterations and modifications if required by the actual geological or geotechnical conditions.

*(iii)* All instrumentation shall be installed in accordance with the manufacturer's recommendations and with the additional requirements specified in this document.

*(iv)* The installed measuring equipment as well as the required space for measuring must be kept free and accessible for all the duration of construction.

*(v)* All instruments shall be protected against damage by blasting and tunnel traffic. Where required protective covers or housings may be used to prevent damage of the instruments.

*(vi)* Readout units as dial gauges or tape extensometers shall be available at any time during tunnel construction. Spare parts and spare units shall be maintained on site.

*(vii)* All instruments and equipment used and required for the geotechnical measurements shall be made available for the inspection/verification of The Independent Engineer throughout the construction period.

**j)** Reading and plotting data

*(i)* Reading of the instruments, data processing and plotting of the measurement results shall be carried out by qualified personnel of the Concessionaire as approved by the Independent Engineer.

*(ii)* For the optical displacement monitoring a software package shall be used which allows a direct data flow. This software shall include features as follows:

- Free stationing of the theodolite and calculation of standard deviation in all three coordinate directions.
- Automatic target identification and recognition of new zero readings.
- Calculation of 3D-coordinates and displacements of any desired point and its radial distance to the theoretical profile.

- Correction of errors based on physical effects.
- Transformation of coordinates after control measurements.
- Measurement results shall be tabulated and presented in graphs.

*(iii)* The software processing data shall include the following features:

- Development of displacements with time, directly associated with tunnel driving activities.
- Plot of displacement vectors within the cross section.
- 3D Displacement vector orientations
- Excavation program related evaluation and presentation of displacements (Influence lines showing the influence of daily excavation on displacements of measuring points).
- Assessment of displacements prior to zero measurement.
- Development of differences in displacement with time e.g. roof settlement minus settlement of top heading footing.
- Calculation of stresses and safety factors or degree of utilisation for the shotcrete lining based on optical displacement monitoring, and time dependent shotcrete strength.
- Other evaluations as required by the Independent Engineer and the Designer.

*(iv)* For the monitoring of geotechnical instruments, a software package shall be used which allows a direct data flow. This software shall include features as follows.

- Presentation of data related to the time and excavation progress within one plot.
- Cross-sectional visualization of measuring anchor and extensometer data.
- Multiple plot capabilities (Forces/Radial strains in rock mass/ displacements).
- Shotcrete stress calculation based on strain measurements and material law for young shotcrete as tested in situ.

*(v)* The first measurements (zero-readings), for each measuring instrument, shall be made immediately after installation or as soon as the particular instrument may allow.

*(vi)* The frequency of the further measurements or readings can be envisaged for each measuring section as follows:

- 1st week: daily
- 2nd week: twice a week
- 3rd & 4th week: once per week
- Later: monthly and bi-monthly
- When the bench is approaching the instrumentation section installed during top heading, reading frequencies shall be increased again.
- The actual frequency of reading will however be influenced by the construction stages i.e. top heading/bench heading in the tunnel and shall be proposed by the Designer through Concessionaire.

*(vii)*Data of the optical displacement monitoring shall be processed on the same day and plots shall be available at late afternoon or as requested by the Independent Engineer. Other data from measurements must be processed within 24 hours after the readings have been taken

and must be plotted. All processed data and visualized diagrams must be available for the Independent Engineer scrutiny at any time. A copy of all records shall be permanently kept on site and made available to the Independent Engineer. If required the Independent Engineer may instruct shorter data processing and visualization time.

*(viii)* The Concessionaire has to immediately inform the Independent Engineer in case he observes obvious unusual and unexpected readings or makes other unusual observations in the tunnel.

**k)** Methods of data evaluation and interpretation - According to their geo-mechanical relevance, the main monitoring parameters for tunnelling shall be as follows:

*(i)* Time – Displacement Diagrams, Magnitude of Displacements Time- Displacement diagrams shall show the development of the displacement of one point versus time. Time-displacement diagrams shall be generated for all three components of the displacement vector (vertical, horizontal and longitudinal displacement). Construction phases (top heading, bench, and invert) shall be shown on the same diagram to allow for an easy correlation between displacement behaviour and construction activities.

*(ii)* Distribution of Displacement Vectors in Cross-section

*(iii)* Displacement Vector plots shall allow the representation of the cross-sectional displacements and their development with time. Displacement vector plots shall allow the detection of weak zones and / or faults outside the excavation area. They shall provide additional information about the rock mass structure and deformation phenomena close to the tunnel.

*(iv)* Lines of Influence - Lines of Influence shall be produced by connecting displacement values of a number of monitoring points along the tunnel axis at the same time, similar to a “deflection curve”. Normally, a number of lines for a specified time span shall be shown on one plot. In addition, construction phases (top heading, bench and invert) shall be shown to allow for an immediate correlation between measured displacements and construction activities

*(v)* Trend Lines - Trend lines shall be generated by connecting settlement values of individual lines of influence at a predefined distance behind the face.

*(vi)* Development of Longitudinal Displacements close to the excavation face: This shall indicate changes in ground stiffness ahead of the face.

*(vii)* Trend of advancing displacements due to bench excavation: This shall reflect the influence of individual bench excavation steps on the already excavated tunnel sections.

*(viii)* Development of Differential settlements: This displacement option shall be used to show the difference in displacements between two monitoring points belonging to the same monitoring section.

- Usually the difference in settlements shall be displayed between: Crown & side wall ($S_{crown} – S_{sidewall}$) = $\Delta S$
- $\Delta S$ for both side walls shall be observed.
- for horizontal displacements between: Left and right side wall ($H_{left} – H_{right}$) = $\Delta H$

*(ix)* Control limits for Trigger (Alert, Action & Alarm) levels shall be defined by the Concessionaire for the monitored parameters (including the control parameters) based on the design and anticipated ground behaviour and support performance.

*(x)* The examples of control parameters are:

- Displacement velocities derived from 3D absolute displacement

- monitoring
- Differential Settlements
- Trend Lines(increase in displacements corresponding to face advancement)
- Shotcrete strains derived from strain measurements with shotcrete strain meters in the shotcrete lining.

**l) Submissions**

*(i)* The Concessionaire shall submit his designed instrumentation, monitoring and reporting scheme to the Independent Engineer to seek his Notice of No Objection. This scheme shall be designed to achieve the objectives stated in this document.

*(ii)* In order to complete the above scheme, the Concessionaire shall refer to the information provided with the Contract documents and supplement this with his own GI as required by the Contract. This scheme should give due emphasis to the information provided with the Contract documents and shall include following, as a minimum.

(a) Ground conditions including the geotechnical properties of the different soil and rock layers.

(b) Adjacent EBS within the zone of influence including their existing condition and foundations as available.

(c) Proposed method of construction, and the type of equipment proposed.

(d) Assumptions and calculations for the basic design including the installation of appropriate instrumentation for monitoring and recording ground and groundwater movements, settlements & displacements, deflections, tilts, rotations, distortions, cracks, Performance of tunnel ground support (both in bored and NATM tunnelling works), pressures, loads/stresses & strains (including that in structural elements for the support of excavations and tunnel supports) and the like.

(e) Proposed types of instrumentation, locations (including that of monitoring sections along with their types and details in NATM works) of and programs for establishing the base readings and continuous observations.

(f) Proposed methodology for installation (including proposed installation programme & procedures, Quality Assurance Plan along with proposed tests for quality control, Site organization plan for deployment of Concessionaire's personnel), calibration (including function testing and acceptance tests), maintenance and operation/running (including Data Collection/ Data transfer systems; type and presentation of output to be produced by the Concessionaire) of the instrumentation system, including location of gauge houses, proposals for de-airing of piezometers and any other special requirements.

(g) Frequency of the monitoring/data recording h) Trigger (Alert, Action & Alarm) levels for each and every instrument and each and every parameter to be monitored.

(h) Frequency of reporting monitoring records to Concessionaire's construction site staff and to the Independent Engineer.

(i) Possible preventive and remedial measures to be adopted to ensure that the trigger levels are maintained within acceptable limits.

**m) Types of Instrumentation**

*(i)* The types and quantities of geotechnical instrumentation shall be proposed by the Concessionaire, for the acceptance of the Independent Engineer. Instruments of robust nature shall be used which are capable of giving reliable data within the manufacture's tolerances over long periods of measurement.

*(ii)* The Concessionaire shall establish suitable temporary benchmarks for the purpose of monitoring vertical movements. Such bench marks shall be outside the zone of influence of construction.

*(iii)* Precise levelling points shall be provided on monuments at ground level to extend throughout the area where predicted settlement is expected to exceed 5 millimeters.

*(iv)* Precise levelling studs (road nails) shall be installed on highway (on Roads) and pavement areas in array at 90 degrees to the tunnel alignment. These arrays shall extend to the outer edges of the 5 millimeters predicted settlement contour lines. Suitable monitoring points which cannot be readily disturbed shall be installed over open/park areas.

*(v)* Precise levelling shall be carried out of survey monuments and of settlement monitoring points on EBS sufficient to determine the imposed strain. Where the structures are subjected to protective works, electro-level beam systems shall be employed, with a back-up system relying on the use of precise levelling pins also installed.

*(vi)* Precise levelling points/ devices are to be provided for levelling of the tunnel crown and other specific points (side walls etc.) during tunnel excavation to monitor settlements and bottom heaves.

*(vii)* Piezometers (vibrating wire, pneumatic, Casagrande and standpipe) are to be provided in the ground for measuring changes in piezometric pressure at different depths. The type of piezometer required will be determined by the anticipated response times.

*(viii)* Inclinometers, strain gauges and extensometers in the ground and within diaphragm walls/secant pilling wall (or retaining structures) are to be provided for measuring lateral displacements. The depth of the instrumentation in the ground shall extend beyond the influence zone of the Works with respect to ground movement and excavations and shall be fixed at least 1 metre below the bottom of the diaphragm wall/secant pilling wall (or retaining structure). In case diaphragm wall/secant pile wall (or retaining structure) which has terminated above the final excavation level then the inclinometer shall extend at least 1m below final excavation level and/or into a hard stratum where there is no ground movement. Inclinometer for slope stability shall be provided. The depth of the instrument for slope stability shall extend at least 1m below the final excavation level and/or into a hard stratum where there is no ground movement.

*(ix)* Extensometers and convergence bolts are to be provided to measures convergence at tunnel openings or at any other critical sections. Borehole extensometers shall be provided in soft grounds to monitor heave and vertical deformations with depth.

*(x)* Load cells shall be installed at selected struts and anchors in excavations to enable design predictions to be verified and to monitor performance.

*(xi)* Targets (Reflectors) shall be provided for determining 3D-coordinates and monitoring 3D-absolute displacements to track the target movements in space which shall allow a realistic assessment of deformation behaviour of the tunnel.

*(xii)* Strain meters shall be used for determining the stress development in the shotcrete lining by measuring strains. They shall be installed pair wise to allow determination of sectional forces such as normal thrust and bending moments. Strain meters shall be temperature compensated to compensate for temperature increase of the shotcrete during the hardening process.

*(xiii)* Shotcrete Creep Test Equipment: An in-situ shotcrete creep test stand shall be installed in the vicinity of the excavation. It shall consist of a hydraulic piston with precise automatic load control, strain measurement installation on one specimen (200x200x400mm), temperature measurement installation within the specimen as well as shrinkage monitoring on two, non-stressed specimens. The specimen shall be produced by means of the shotcreting equipment and shotcrete used for regular support. Time dependent stress levels shall be applied to the specimen and by means of the resulting stress-strain-time relation necessary parameters for the shotcrete material law shall be generated.

*(xiv)* Radial pressure cells shall be used for measuring the development of ground pressure acting on the tunnel lining. They shall be of size 300 x 300 mm and regrettable. Readings shall be taken in a remote-controlled manner with electrical transducers.

*(xv)* Tangential Pressure cells shall be used for determination of shotcrete lining stress. They shall be installed in areas of special interest such as intersections etc. They shall have a dimension of 100 × 200 mm. Readings shall be taken in a remote-controlled manner with electrical transducers.

*(xvi)* Rock bolt axial force meter shall be used to determine the load development along the anchor. This will provide information on the increase in load from the anchor tip to the anchor plate. Measuring anchors shall be installed together with rock bolt load cell and extensometers.

*(xvii)* Rock bolt load cell shall be installed at the anchor plate to get information on the maximum anchor load and the degree of utilization of the anchor.

*(xviii)* Tilt meters shall be provided on walls of adjacent EBS where tilt has been identified as being critical.

*(xix)* Crack meters shall be installed to monitor existing and new cracks on applicable EBS.

**n) Monitoring and Reporting**

1. The Concessionaire shall propose details of the performance monitoring of the Works and shall define appropriate trigger (Alert, Alarm and Action) levels for each EBS, each of the proposed instrument, each parameter to be monitored for Geotechnical and Bored tunnel works and each parameter/control parameter to be monitored for NATM works (to monitor ground behaviour and performance of the support). These trigger levels shall be defined by the Concessionaire and submitted for the acceptance of the Independent Engineer. Any changes to these trigger levels during the Works shall be subject to the Notice of No Objection from the Independent Engineer.
2. The general definitions for the trigger (Alert, Action & Alarm) levels are given below.
    i) **"Alert Level"** shall initially be set as 0.5 times the serviceability limit value defined for the monitored EBS/Instrument/parameter for Geotechnical and Bored tunnel works/ parameter and control parameter for NATM works.
    ii) **"Action Level"** shall be set at 0.8 times the serviceability limit value defined for the monitored EBS/Instrument/parameter for Geotechnical and Bored tunnel works/ parameter and control parameter for NATM works.
    iii) **"Alarm Level"** shall initially be set at the serviceability limit value defined for the monitored EBS/Instrument/parameter for Geotechnical and Bored tunnel works/parameter and control parameter for NATM works.
3. The serviceability limit value for a monitored element/parameter shall be the lesser of:
    *(i)* calculated design value for the serviceability limit, including stresses and displacement/movement of geotechnical, bored tunnel and NATM tunnel works ;
    *(ii)* monitored element movement/distortion which would theoretically cause service disruption.
    *(iii)* For utilities, the values of settlement/rotation those are acceptable to the Relevant Agencies/Authorities and/or the Independent Engineer.
    *(iv)* allowable structure or ground limits corresponding to "Slight" Damage Classification – refer Table 3.1 below.
    *(v)* Groundwater drawdown (a drop of water table during construction) by one metre below the lowest recorded groundwater table (the lowest recorded groundwater table shall be considered as the lowest level of groundwater table as recorded by the Concessionaire prior to the construction).

4. If any of the trigger levels is reached, the Concessionaire's Response shall comprise of emergency actions which could include the following and other necessary measures.

    a. On reaching an "Alert Level' at any location, the Concessionaire shall immediately submit a written report to the Independent Engineer,

        - reviewing all total and differential movements/distortions (or the relevant parameters) to date,
        - assessing the effects of the movements/distortions (or of the relevant parameters) on the monitored elements and
        - predicting further movement (or further deterioration of the parameter) and their effect on monitored elements based on the trend to date.

    b. Where it is considered and agreed by the Independent Engineer that movement (or the relevant parameter) trends indicate that "Action Level" may be reached during the course of the Works, the Concessionaire shall be required to submit proposals for remedial measures to limit further movement (or further deterioration of the parameter) for seeking the Notice of No Objection from the Independent Engineer. The remedial proposals shall include details of the remedial measures and their likely efficiency. Notwithstanding the above, a change between consecutive readings greater than 5 millimeters (movement) shall necessitate the imposition of "Alert Level" status regardless of the global movements.

    c. On reaching an" Action Level" at any location, the Concessionaire shall submit an updated report

        - reviewing the movements including differential movements and distortion (or the relevant parameters). The report shall assess the effects on monitored elements and predict further movement (or further deterioration of the parameter) and their subsequent effect on monitored elements. The report shall allow for remedial works that have been implemented and shown to be effective.

    d. Where it is considered and agreed by the Independent Engineer that movement (or relevant parameter) trends indicate that "Alarm Level" may be reached or exceeded during the course of the Works, the Concessionaire shall reassess the design and propose remedial measures (including design modifications) for seeking the Notice of No Objection from the Independent Engineer. The Concessionaire shall propose a Contingency Plan that shall be implemented in the event "Alarm Level" is reached or exceeded and obtain Notice of No Objection from the Independent Engineer. The Concessionaire shall also develop an Emergency Plan that shall be implemented in the event the applied contingency measures cannot control the situation and obtain Notice of No Objection from the Independent Engineer. In addition, a new set of "Alert Level" and "Action Level" values which take into account the implementation of the proposed remedial works shall be proposed by the Concessionaire for seeking the Notice of No Objection from the Independent Engineer before work may be allowed to continue. The Concessionaire shall also provide a report after the remedial measures (including the design modifications) have been implemented, detailing the full history of movements (or other relevant parameters) and effects of implemented remedial measures in relation to the actual construction work. The report shall also contain the review and interpretation of events along with a justification to proceed with the Work for seeking the Notice of No Objection from the Independent Engineer. Work shall only be resumed after a Notice of No Objection has been received from the Independent Engineer.

    e. In case an "Alarm Level" is reached or likely to be reached, all excavation works shall be suspended within 30 meters (or as required) of the instrument/or affected portion of the Works. The Concessionaire shall immediately implement the measures as defined in the Contingency/Emergency plans to make the related part of the Works safe and control the

situation. The Concessionaire shall provide a report detailing the full history of movements (or other relevant parameters) and an interpretation of events to the Independent Engineer. To resume the suspended work, the Concessionaire shall demonstrate to the satisfaction of the Independent Engineer that it is safe to do so. The Suspended Work shall only be resumed by the Concessionaire after a Notice of No Objection has been obtained from the Independent Engineer.

f. Throughout the construction period, all adjacent EBS shall be subject to regular inspections by the Concessionaire's Independent Engineers. Signs of distress in any structures shall be recorded and steps taken to immediately alleviate such distress.

**o) Frequency of Reporting**

(1) Sufficient time shall be allowed between installation of instruments and commencement of relevant site activities to enable a reliable set of base readings to be established for all installed instrumentation. These time scales shall be agreed with the Independent Engineer when the Concessionaire submits his proposed instrumentation scheme.

(2) All instruments shall be connected to data logging equipment where possible so that measurements can be made on a continuous 24 hour basis. Data shall be accessible via computers in the Independent Engineer's site offices. An alarm system shall be incorporated into the computer network, with the alarm being activated if gauge readings exceed any of the agreed Alert, Action and Alarm levels. In addition to that, the excavation works for the cut & cover and shafts shall be monitored by applying On Site Visualization (OSV) monitoring.

(3) Reports on monitoring results shall be submitted to the Independent Engineer within 24 hours. A detailed graphical presentation of historical values of monitoring shall be submitted on a weekly basis in a format agreed with the Independent Engineer. All results/information shall be submitted to the Independent Engineer weekly on virus-free digital storage devices. The information on the storage devices must be retrievable using Microsoft Excel software running on IBM PC or compatible systems. Where a greater frequency of monitoring is required than on a 24-hour cycle, the Concessionaire shall submit the reading taken directly at the site to the Independent Engineer on the same day.

(4) All instruments shall be suitably protected against accidental damage, vandalism and adverse climatic conditions. Any damaged instrument shall be replaced immediately, with a set of base readings being taken as soon after installation as practicable.

(5) The observations so recorded from various instruments should be kept in such a fashion, which can function as evidence if required in any legal disputes and should help the owner responsible for construction for framing their replies and other related legal paperwork.

(6) The Concessionaire shall permanently record in both hard and soft (electronic) form for future reference as required all readings and observations from each installed instrument. On the Monday of each week the Concessionaire shall provide to the Independent Engineer the updated records (in both hard and soft copy) for all instruments. These records shall show all previous readings in both numerical and graphical form and include the location, type and trigger levels for each instrument, noting any exceedances and any changes to the instrumentation location, type or records.

(7) The Concessionaire shall permit access to the Works for personnel from academic/research institutions as approved by the Authority so that they can collect relevant data for making studies on performance of various underground construction elements. The Concessionaire shall make all such instrumentation data freely available to these academic/research institutions for academic/research purposes only

**p) Protection, Maintenance and Repair**

1) The Concessionaire shall protect and maintain in good working condition all monitoring instruments

and devices throughout the Contract period. Any instrument or device deemed critical to the Works that is not functioning properly or accurately shall be replaced immediately at the Concessionaire's own cost.

2) The Concessionaire shall ensure that all instruments and devices accessible to public shall be protected with sturdy lockable boxes.

**q) Removal**

1) No instrument or device shall be demolished, abandoned, removed, disposed of or rendered inaccessible without the agreement of the Independent Engineer.

2) All instruments and devices shall be removed on final acceptance of the Works. All terminal boxes and covers shall be removed and disposed of. All boreholes and excavations shall be completely filled with concrete or required grouting agent with proper procedures as per codes and all instruments and devices attached to EBS removed to the satisfaction of the Independent Engineer.

3) All costs incurred in the satisfactory removal of the instruments and devices are deemed to be included in the Contract rates and prices.

## 3.4 EBS Protection

### i. General

(1) The Concessionaire shall be responsible for the control of all ground movements and distortions and for any resulting damage to EBS. During the Preliminary Design phase, the Concessionaire shall investigate all EBS that may be influenced by the Works and establish allowable movement and distortion criteria for each individual or group of EBS. The Concessionaire's EBS study shall extend to a certain distance beyond the potential influence zone on each side of the tunnel alignment centerline and also to a certain distance beyond the potential influence zone on each side of the approach cut & cover alignment centerline. The respective influence zones and the distances beyond these influence zones, where EBS study shall have to be conducted by the Concessionaire, shall be proposed by the Concessionaire with the required backup details during the Preliminary Design Phase for the acceptance of the Independent Engineer.

(2) For operating rail tracks, maximum permissible total movement shall not be greater than 15 millimeters or as agreed by the Concerned Rail Authorities. Angular distortion to rail tracks shall be limited to an absolute maximum of 5 millimeters in 10 meters (1:2000) longitudinally, and 1 in 2500 transversely as measured across any one single track set. These requirements are in addition to any other requirements imposed by applicable government/other agencies, utility companies/authorities and the Authority.

(3) The Concessionaire shall design both his Temporary and Permanent Works to ensure that ground and EBS movements and distortions are maintained within tolerable limits and that operation of EBS, Roads and pavements are not affected by the movements and distortions. The Concessionaire shall also design these Works such that groundwater regime is not affected post-construction stage and the changes to the groundwater level do not exceed normal seasonal variations during Operations Phase of the Project.

(4) The Concessionaire shall obtain a Notice of No Objection from the Independent Engineer and relevant Agencies/Authorities and/or utilities companies prior to carrying out any dewatering of the ground. Dewatering may only be carried out within contained excavations once the walls or water cut-offs/barriers which provide that containment are all in place and proven to be effective to the satisfaction of all interested parties and the Independent Engineer.

(5) The Groundwater drawdown (a drop of water table during dewatering/construction) outside the excavation/adjacent to works, shall be controlled such that the water table doesn't get lowered by more than one metre below the lowest recorded groundwater table (the lowest recorded groundwater table shall be considered as the lowest level of groundwater table as recorded by the Concessionaire prior to the

construction). For ensuring this the Concessionaire shall provide recharging well system, if required.

(6) The Concessionaire's attention is drawn to the Conditions of Contract and Authority's Requirements relating to repair of damage should any arise as a result of the Concessionaire's construction activities.

(7) The Concessionaire shall take due regard of the presence of all utilities and services within and adjacent to the Works.

(8) The Concessionaire shall instrument and regularly monitor the ground and EBS adjacent to all excavations to determine the rate and magnitude of any movements and distortions.

(9) Movement and distortion shall be limited such that any individual EBS shall not suffer damage greater than "Slight" as defined in the "Damage Classification" in Table 3.1.

(10) Movement and distortion to critical/sensitive structures such as hospitals, bridges, flyovers, underpasses/sub-ways, viaducts, heritage structures and "protected" structures etc. shall be limited to "Negligible" as defined in the "Damage Classification" Table 3.1.

ii. **Minimizing Ground Movements**

1) All tunnel (bored and NATM), cut-and-cover and NATM works shall be constructed in such a way that it minimizes ground and EBS movements and distortions by immediate installation of support/pre-support to the ground and by cutting off of any inflow of water into the Works. Care should be exercised to ensure that there is no over- excavation.

2) Construction from the surface shall be undertaken with due regard to the settlement associated with the method chosen.

3) The following support methods shall not be permitted.

a. Use of ground anchors beneath adjacent buildings without the prior approval of the Authority

b. Non-recoverable timber ground support.

iii. **Condition Survey**

1) The Concessionaire shall undertake a condition survey of all structures within the zone of potential influence as determined by the Concessionaire's analysis which are anticipated to incur movements in excess of the action level for Stage 1 specified below.

2) `Structures` includes all surface and sub-surface structures including historical monuments, buildings, bridges, roads, tunnels, utilities, culverts and sewers.

3) The Concessionaire shall determine the potential influence zones for his Works and undertake condition surveys and EBS study and submit for the approval of Independent Engineer in charge.

iv. **Prediction of Ground Movements**

The Concessionaire shall provide predictive assessments of the anticipated ground and EBS movements and distortions within the potential influence zones and a certain distance beyond these influence zones, and submit these predictions to the Independent Engineer when making submittal of his proposed method of construction, and tunnel/shaft support methods

v. **Assessment of Impact on Structures**

1) The Concessionaire shall provide an assessment of the effect of the predicted movement on all structures within the zones of influence and a certain distance beyond these influence zones.

2) The Concessionaire shall assign to each and every EBS that may be affected by the Works one of the risk categories, in accordance with criteria defined in "Damage Classification" in Table 3.1.

3) Movements and distortions shall be limited as defined in clause 3.4.A above.

4) Depending upon the level of risk, the Concessionaire shall propose precautionary and protective measures and submit these to the Independent Engineer for seeking his Notice of No Objection. Once agreed by the Independent Engineer these measures shall be implemented by the Concessionaire prior to any works within the areas and at no extra cost to the Authority.

vi. **Staged Assessment**

1) The Concessionaire shall assess the effects of movements and distortions on EBS in one, two or three stages, depending upon the findings at each stage, as described below: -

**a) Stage 1 Assessment**

The effect of movement and distortion on EBS foundations is assessed but the pattern of settlement is ignored. Any structure where the predicted settlement is less than 10 millimeters and the predicted ground slope is less than 1/500 need not be subject to further assessment. For critical/sensitive structures, a more stringent slope and settlement criteria shall be adopted to comply with the provisions of clause 3.4.A(10). All other structures within the zone of influence and a certain distance beyond [please refer Clause 3.4.A(1)] shall be subjected to a Stage 2 assessment.

**b) Stage 2 Assessment**

i) The EBS identified to be having a potential risk as a result of Stage 1 assessment shall be individually assessed using a limiting tensile strain approach. This method of assessment takes into account the tensile strains in the ground and uses a simple idealized model of the building. Tried and tested references from the literature may be utilized as an alternative. In case of all Cut & Cover excavations, all NATM tunnelling works and for those EBS that cannot be satisfactorily represented by a simple idealized model of a building, Numerical simulation of ground movement due to construction activities shall be done to assess the settlement/distortion subject to the acceptance by the Independent Engineer. The geological features, such as joints orientation and spacing etc., shall also be taken into account for such analyses, where appropriate.

ii) For critical/sensitive structures and based on their structural condition a more stringent damage classification shall be adopted to comply with the provisions of clause 3.4.A(10).

**c) Stage 3 Assessment**

i) All EBS which are placed in Category 3 or above in the "Damage Classification" in Table 3.1, during the second stage assessment, and also all critical/sensitive structures for which a more stringent damage classification is required to be adopted to comply with the provisions of clause 3.4.1(10), shall be subjected to a further settlement/distortion assessment. A detailed structural survey shall be undertaken by the Concessionaire to determine the structural form and condition of all such buildings/structures, followed by an analysis of how individual elements of the building/structure would be affected by the predicted settlement/distortion. The method, extent and detail of the analysis will be determined on a case-by- case basis and may include, inter alia, an analysis of the soil/structure interaction, structural behaviour, and the possible effects of differential stiffness of the foundations.

ii) As a result of the Stage 3 analysis, the requirement for any protective works shall be established and the details of any protective works including designs and method of working determined. Details of such works shall be submitted to the Independent Engineer for seeking his Notice of No Objection. All such protective works shall be carried out by the Concessionaire at no extra cost to the Authority.

**Table 3.1: Building Damage Classification**

| **Building Damage Classification[1]**<br>**(After Burland et al, 1977 and Bos Cardin and Cording, 1989)** |
|---|

| 1 | 2 | 3 | 4 | 5 |
|---|---|---|---|---|
| **Risk Category** | **Description of Degree of Damage** | **Description of Typical Damage and Likely Form of Repair for Typical Masonry Buildings** | **Approx[2] Crack Width (mm)** | **Max Tensile Strain %** |
| 0 | Negligible | Hairline cracks | Less than 0.1 | 0 to 0.05 |
| 1 | Very Slight | Fine cracks easily treated during normal redecorations. Perhaps isolated slight fracture in building. Cracks in exterior brickwork visible upon close inspection | 0.1 to 1 | 0.05 to 0.075 |
| 2 | Slight | Cracks easily filled. Redecoration probably required. Several slight fractures inside building. Exterior cracks visible: some repointing may be required for weather tightness. Doors and windows may stick slightly. | 1 to 5 | 0.075 to 0.15 |
| 3 | Moderate | Cracks may require cutting out and patching. Recurrent cracks can be masked by suitable linings. Tack- pointing and possibly replacement of a small amount of exterior brickwork may be required. Doors and windows sticking. Utility services may be interrupted. Water tightness often impaired. | 5 to 15 or a number of cracks greater than 3 | 0.1 to 0.3 |
| 4 | Severe | Extensive repair involving removal and replacement of sections of walls, especially over doors and windows required. Windows and door frames distorted. Floor slopes noticeably. Walls lean or bulge noticeably, some loss of bearing in beams. Utility services disrupted. | 15 to 25 but also depends on number of cracks | Greater than 0.3 |
| 5 | Very Severe | Major repair required involving partial or complete reconstruction. Beams lose bearing, walls lean badly and require shoring. Windows broken by distortion. Danger of instability. | Usually greater than 25 but depends on number of cracks | |

**Notes:**

1. The table is based on the work of Burland et al (1977) and includes typical maximum tensile strains for the various damage categories (column 5) used in the stage 2 settlement analyses
2. Crack width is only one aspect of damage & should not be used on its own as its direct measure.

## 3.5 GENERAL

(1) The work shall be carried out in compliance with the Health and Safety requirements as detailed within the Authority's Requirements.

(2) All work shall be carried out in compliance with the Acts, Rules and Regulations of Government of India & Government of Karnataka State.

(3) The Material and Workmanship Specifications shall be adopted by the Concessionaire and their Designer(s) considering the chosen methodology. The Concessionaires Material and Workmanship Specifications shall as a minimum comply with all applicable Indian Standards and Codes and relevant International Standards and Codes as applicable.

(4) The specifications contained in this section are the minimum expected to achieve the performance requirements of design and execution.

## 3.6 SURVEY

(1) Before commencement of any construction work, the Concessionaire shall prepare and submit appropriate survey method statements relating to his proposed methods of working.

(2) The Concessionaire shall establish a system for underground surveying, setting out and correcting deviations from theoretical alignment, using a laser-based system. Reference points and targets shall be used in conjunction with lasers to ensure the accuracy of the system and it should be easy to monitor by the Independent Engineer. Laser-based guidance systems should have an alternative system as back-up.

(3) In the case of tunnel boring machines, where construction shall be computer controlled, the Concessionaire shall use appropriate software for ring selection logic steerage logic, etc.

(4) If at any time during the excavation of the tunnel, it is evident that the alignment for the tunnel is outside the specified/permissible tolerances then, before proceeding further with the excavation, the Concessionaire shall submit his proposal for the necessary corrections to the alignment, and the Concessionaire shall forthwith make the corrections as accepted by the Independent Engineer.

## 3.7 FIELD CONTROL AND MONITORING EQUIPMENT

**1) Setting out of Line, level and Profile**

Prior to starting underground work, the Concessionaire shall submit to the Independent Engineer proposals on the setting out the Works and for correcting any deviations.

2) **Chainage**

Markers shall be provided in tunnels at 10 m intervals. The markers shall be painted in white durable paint.

**3) Markers and Benchmarks.**

The Concessionaire shall provide the Independent Engineer with the location and description of all survey stations, and all survey data.

### 3.7.1 Monitoring Equipment

(1) **For Monitoring inside the Tunnel:** The Concessionaire shall provide basic equipment for measurement of deformations and alignment inside the tunnels, at least by using levelling instruments, wire extensometer for convergence measurement, 3 D optical targets for 3D displacement monitoring. The instrumentation scheme shall be proposed by the Concessionaire and agreed by the Independent Engineer.

(2) **Ground Surface Monitoring:** The Concessionaire shall provide Instrumentation and monitoring scheme for measurement of ground settlement along the tunnel axis and upto the influence zone in transverse direction.Such ground improvements shall be monitored by providing ray of ground settlement markers at particular intervals and the frequency of the measurement of these settlement markers shall be defined with respect to the advancement of the tunnel. The detailed scheme shall be proposed by the

Concessionaire and agreed by the Independent Engineer.

(3) **Monitoring of critical Utilities and Buildings in the influence zone of Tunnel axis:**The Concessionaire shall provide Instrumentation and monitoring scheme for the sensitive structures and utilities falling in the influence zone of the tunnel drive. The instruments can be Tilt meters, 3D Targets, Settlement Markers etc. The detailed Instrumentation and Monitoring scheme shall be proposed by the Concessionaire and agreed by the Independent Engineer. In critical locations online monitoring shall be proposed by the Concessionaire and shall be agreed by the Independent Engineer.

(4) During the execution of excavation works, the Concessionaire needs to procure supplementary types of equipment as may be required for standard tunnelling methods.

(5) Measurements of all types of equipment shall be performed by the Concessionaire as directed by the Independent Engineer. Results from each measurement shall be submitted to the Independent Engineer within 24 hours.

(6) The instrumentation and monitoring system shall include the real-time information from the TBM control parameter operations. In case any sensitive structure is identified which requires close monitoring, real time instrumentation and monitoring system shall be established.

## 3.8 TUNNEL BORING MACHINES (TBM)

### 3.8.1 General

(1) The Concessionaire shall be fully responsible for the selection, design and supply of suitable TBM machines and ancillary plants and equipment.

(2) The Concessionaire shall take into consideration all geological and other relevant parameters applicable for the Concession reach. He shall satisfy himself to the suitability of the TBM Shield machines for the ground conditions to be excavated.

(3) The Concessionaire shall make all arrangements and provide all the labour, plant, equipment and materials necessary at the TBM launch and reception shafts for TBM excavation. The Concessionaire shall co-ordinate the required delivery arrangements with the manufacturer suiting the site constraints.

(4) The Concessionaire shall be responsible for the erection and commissioning of the TBM and all back-up equipment required to allow the TBM to commence excavation in a fully operational condition in all respects and in accordance with the manufacturer's recommendations.

(5) The Concessionaire shall be responsible for the design and installation of the temporary TBM launch structures and for ensuring they are satisfactory in all respects for receiving and assembling the TBM components. The shaft walls (or other structures) and surrounding ground shall have sufficient capacity to sustain without excessive deformation the thrust from the TBM shove-rams during the launch of the TBM.

(6) The Concessionaire shall be responsible for the design and installation of the temporary/permanent TBM retrieval structures and for ensuring they are satisfactory in all respects for TBM breaking-in, receiving the TBM and dismantling and removing the TBM components. The shaft walls (or other structures) and surrounding ground shall have sufficient capacity to sustain without excessive deformation the thrust and torque from the TBM during the breaking-in operations.

(7) The Concessionaire shall be responsible for the provision of any and all ancillary structures at the shaft bottom and for coordinating design and configuration of such ancillary structures with the TBM manufacturer.

(8) The Concessionaire shall provide and regularly maintain a mechanical lift of adequate capacity at his main working shafts that complies with all applicable safety standards for the vertical movement of people.

### 3.8.2 General Requirements for TBM

(1) TBM shall be robust with adequate safety margins for the anticipated duty, designed and manufactured to comply with all the Standard BS EN 12336.

(2) The external diameter of the TBM shall be designed to produce minimum over-break and the least necessary clearance for the proper construction of the tunnels. Design shall take into account the horizontal and vertical alignment. Provision shall be made to limit and correct the roll of the machine.

(3) TBM shall be self-propelled. Where propulsion is by means of hydraulic rams thrusting off previously constructed segmental lining, shove-ram shoes and shoe-facings shall be designed to distribute the thrust without causing damage to the as-built lining.

(4) Shove-rams shall be capable of operating individually or collectively in any combination. The shove-rams shall permit the insertion of a key closing segment, in any location.

(5) The TBM shall have Segment erection systems capable of lifting and placing segments safely. Lifting and gripping systems shall be designed to handle the loads with an adequate factor of safety and without damaging the segment and segment sealing systems. Segment erection systems shall be capable of compressing all joint gaskets.

(6) The erector shall be in clear view of the operator. A safety device shall be fitted to avoid accidental release of segments during lifting, handling and placing.

(7) There shall be adequate access to all areas of the TBM where work, including maintenance, may be carried out. A clear means of egress in an emergency shall be provided and always maintained. Minimum dimensions shall conform to appropriate international standards.

(8) Arrangements for extraction, transport and disposal of spoil shall be appropriate for the material to be handled.

(9) Alignment control

- The Concessionaire shall ensure the TBM is provided with a suitable guidance and control system capable of providing the necessary survey information such that the TBM operator is able to accurately control the TBM and tunnel alignment to within the required tolerances.
- The guidance system shall have the capability to predict ahead of the face and to determine the inclination, line, level, roll and pitch of the TBM.
- Detailed guidance information shall be checked against the tunnel alignment control at regular intervals.

(10) All information and data shall be clearly displayed in the TBM operator's control panel and shall also be linked to a data-logging system.

### 3.8.3 Particular Requirements for TBMs

(1) The TBM cutter-head shall be capable of clockwise and anticlockwise rotation and shall only be able to excavate the ground whilst the hydraulic rams are being actuated. The design shall ensure that the cutter-head can be retracted back from the unexcavated ground to minimize the risk of the cutter-head jamming and to facilitate maintenance.

(2) The cutting tools shall incorporate wear detection systems. The cutter-head discs and/or picks shall be able to be renewed from the rear of the cutter-head and shall be interchangeable.

(3) Where boulders could occur at the tunnel face, the TBM design shall permit a boulder of at least 300 millimeter across its smallest cross-sectional dimension to be pushed through the cutter-head. The TBM shall have the capability to handle, break up and remove such boulders through the screw conveyor, slurry discharge aperture or other spoil discharge system with the use of special crushers.

(4) The TBM shall be designed to allow forward drilling through the cutter-head for the purpose of investigating ground conditions ahead of the TBM or to undertake ground treatment to the face.

(5) Grouting facilities

a) The TBM shall be designed to enable the void behind the segments to be grouted continuously and completely from the shield while excavating. The grout ports shall be incorporated within the shield tail-skin.

b) There shall be a minimum of eight grout ports, one in each octant of the shield tail-skin circumference. The TBM shall have the facility and the capacity to inject grout simultaneously through all the grout ports.

c) The TBM design shall enable the grout pipes to any individual port to be cleaned or replaced from within the shield in the event of a blockage without impairing the performance or preventing the use of any other grout port. At least one grout port in each octant of the shield shall be always operational

and available for grouting during shield advancement.

d) Grout pressure and flow rates shall be maintained and monitored at all times whilst the TBM is advancing. The shield shall incorporate automatic systems for monitoring and controlling the volume and pressure of the grout being delivered to the tail void.

(6) The TBM shall be equipped with the facility to generate foam conditioners and deliver them to the cutter head during excavation.

(7) The TBM shall be designed for and equipped with a supplemental ground stabilisation system. This system shall comprise regularly spaced grout ports built into the shield for grouting the ground ahead of the tunnel face. The location and number of ports shall be adequate for the implementation of face stabilisation measures needed for access to the face in all ground conditions. All ports shall be readily accessible and fitted with valves.

(8) The cutter-head shall be articulated such that the cutter-head can be retracted from the excavated face and can be turned in any plane so that it is at an angle to the main body. The TBM must be capable of negotiating 300 metre radius horizontal curves.

(9) The TBM shall be capable of being operated in a closed face mode, such that they can be operated in a closed face mode wherever the encountered ground conditions and water in- flow conditions so demand. All closed face TBM shall be designed to maintain pressure on the excavated ground at all times. The TBM shall be able to balance the total overburden pressure (including hydrostatic pressure) and shall be capable of varying the face pressure as the overburden pressure changes. Earth pressure sensors shall be located at the crown, at TBM axis level and at the invert of the chamber.

(10) All closed face TBM shall incorporate a two-compartment air-lock for man access to the cutter-head and face as per BS EN 12110. Pre and Main Chamber shall have capacity of three and two seats respectively with CCTV and drinking water facility.

(11) Where a screw-conveyor is used, the discharge gate on the screw-conveyor shall be fitted with an accumulator which automatically closes the gate in the event of a power failure.

(12) TBM shall incorporate a system which enables the face to be closed expeditiously to avoid any ground loss in the event that unstable ground is encountered or water in-flow in encountered during the drive. This shall take the form of minimum two independently hydraulically operated gates within the plenum and bulkhead chamber of the TBM. The design needs to have a Notice of No-objection by the Independent Engineer.

(13) The TBM shall be fitted with a data-logger which shall be linked by the Concessionaire to a colour monitor display (to be provided by the Concessionaire) in the Independent Engineer's office. Each TBM shall have its own dedicated colour monitor. The data-logger shall display and record information in real time and shall have the facility to store all accumulated data from the tunnel drive and to read and display past data. As a minimum the data-logger shall record and report the following information.

a) Start and finish time of the excavation stroke.

b) Stroke number, chainage and guidance system's prediction of the next ten strokes after each build.

c) Numbers of thrust cylinders, location and pressures used during the stroke.

d) Extensometer readings of thrust cylinders at the start and end of the stroke.

e) Articulation cylinder position at the start and the end of the excavation stroke - articulation angle.

f) Amount of TBM roll at start and end of the excavation stroke.

g) Cutting direction, speed, pressure/torque of cutter-head.

h) Shield position and attitude for each ring.

i) Earth pressure readings throughout the excavation stroke at the plenum chamber and screw-conveyor.

j) Volume and pressure of grout are injected per stroke. Pressure shall be measured at the point of injection.

k) Volume, type and location of ground conditioners added per ring and the cumulative amount per shift with the concentration value.

l) Quantity of tail grease consumed per shift.

m) Speed and torque of screw conveyor

n) Rate of advance of TBM

o) Use of copy cutter, amount and location

p) Gas detector sensors readings

(14) All data-loggers and ancillary equipment shall be fully operational at all times and shall be maintained by the Concessionaire. The frequency of data logging should be 5 sec and should also have live web feed. The Concessionaire shall provide access to TBM guidance system with viewing rights to the Independent Engineer on real time basis.

(15) The main bearing Rating Life (L10 lifetime as per ITAtech report No1- April 2013) shall be minimum double the expected project operation time according to the ITA guidelines for main drive calculation. The bearing shall be equipped with HBW labyrinth sealing.

(16) The TBM tail skin shall be fitted with three rows of tail wire brush and grease seal system that prevents the ingress of water, excavated material and/or grout into the TBM operational area. Facilities shall be provided for replacing the tail wire brush and grease seals from within the excavation / tunnel. The Concessionaire shall provide grout check "plates" located at the rear of the tail skin, to limit grout migration (from back grouting of the installed segments) along the shield towards the cutter head. An emergency tail seal shall be available in the event of a significant breach of the main seal.

(17) A gas detection system shall be installed on the TBM for monitoring and recording the levels of toxic gases that may emanate from the ground and the tunnel construction equipment.

(18) The Concessionaire shall provide adequate forced ventilation, which complies with:

- maintaining of humidity level below the maximum permitted level for workers during all weather conditions at work site.
- maintaining minimum air-flow and oxygen requirements within the tunnel and at the tunnel face as per condition of Concession for Health, Safety and Environment.

(19) The Concessionaire may obtain and use previous TBM data logs of TBM drives in the vicinity for better optimization of TBM drive and TBM design.

### 3.8.4 TBM Submittals

a) Within 30 days after the Commencement Date, the Concessionaire shall submit the following to the Independent Engineer for no objection:

i. General arrangement of main TBM drive and reception shaft sites showing construction layout during TBM launch and retrieval and back-up equipment. Show that the TBM can be assembled and disassembled within the work site areas.

ii. Performance specifications of the TBM, back-up plant and equipment

iii. Assumed dead loads used in the design or actual loads of the main TBM components

iv. Details of the relevant specifications used

v. Details of TBM control systems

b) The Concessionaire shall submit to the Independent Engineer for non-objection a detailed schedule for the manufacture of the TBM, back-up plant and equipment including delivery dates and testing dates. The Concessionaire shall update progress on a weekly basis and comment on the future necessary action to maintain delivery date.

c) Within 90 days after the Commencement Date, the Concessionaire shall submit to the Independent Engineer for non-objection, all details of the TBM and back-up equipment, including all items specified herein.

d) The Concessionaire shall demonstrate that the TBM manufacturer has manufactured at least three TBMs of similar type, size, and complexity, used in successfully completed similar size projects.

e) The Concessionaire shall submit method statements to the Independent Engineer for non-objection, data

and records at least 90 days before commencement of tunnelling operation. Method Statements shall include:

i. Operations making up normal tunnel construction cycle and associated logistics to include, but not limited to, face support, tunnel excavation, lining erection, shift organization and control, and logistical supply.

ii. TBM operations covering all intended machine parameters and interlocks along tunnel route, taking account ground conditions as defined in the Concessionaire s Geotechnical Interpretative Report completed. The method statement should include, but not be limited to, the precise start-up procedure, cutter head rotation speed and torque, screw volumetric control, TBM thrust, rates of advance and planned maintenance schedule.

iii. A work plan covering access to excavated face and cutter head for inspection or removal of obstructions, cutter tool changes, maintenance or repair using compressed air, and other supplemental ground stabilization methods as required. This will include details of the TBM airlock or compressed air chamber, its locking and bulkhead designs, the sealing arrangement, the life support requirements and the mechanism supporting the lock inside the tunnel. Include a detailed description of procedures for operating the air lock, affecting compression / decompression, operating details, and emergency work plan.

iv. Proposed method of calculating and monitoring the face pressure required to maintain face stability and the means and methods for changing the pressure as a function of tunnel depth, ground water level, surface settlement, ground conditions and type of ground.

v. Method of launching the TBM in immediate Earth Pressure Balance (EPB) mode including EPB re-start after plenum interventions.

vi. TBM operating procedures that shall be imposed when crossing under or over existing infrastructure located within 1.5 tunnel diameters of the excavated tunnel diameter interfaces.

vii. Break-in/out details

viii. Method of maintaining EPB or slurry pressure where necessary

ix. Operation of TBM guidance system, including translation of information on alignment drawings into input for the guidance system

x. Procedure for back-up survey checks in tunnel behind TBM weekly or whenever the laser is reset, whichever is more frequent

xi. Description of how corrections will be implemented if a completed tunnel lining ring is built using up more than 50 percent of tolerances specified herein

xii. Details of probing ahead, including drilling equipment and type of radar system

xiii. Spoil and slurry handling in the tunnel and shaft including suitable methods to transport the spoil and slurry safely and efficiently to the surface

xiv. Spoil and slurry treatment including separation plants, and disposal locations and haul routes of spoil haulage

xv. Construction water supply system for the TBM

xvi. Temporary drainage, power lighting and ventilation systems

xvii. Temporary communication systems

xviii. Layout and description of proposed gas monitoring systems for TBM and the tunnel

xix. Response to activation of gas detectors alarms

xx. Fire detection and suppression equipment on the TBM and in the tunnel, including details of the TBM refuge chamber

xxi. Emergency evacuation drill for individuals and entire underground crew

xxii. Soil conditioning and slurry materials, composition, mixes, target injection rates including environmental acceptance testing regime

xxiii. Procedure for manually steering the TBM and selecting ring types and roll correction in the event of malfunction in the TBM guidance system

xxiv. Frac-Out and Surface Spill Contingency Plan: The Concessionaire shall submit a Frac-Out and Surface Spill Contingency Plan describing procedures for preventing drilling fluid losses or spills or fluid returns to the surface. The plan shall address observations to be made and plans for containment and clean-up, if spills or hydro- fracture occur. The plan shall also address changes that may be required to Concessionaire 's operations to avoid recurrences.

xxv. Water Control Plans:

a) Submit temporary drainage provisions and details for the control, treatment, and disposal of groundwater and construction water:

b) Provide details of pumping systems, sumps, primary and backup power systems, flow meters, and piping for removing groundwater and construction water from the tunnel.

c) Provide details to prevent flooding and accumulations of water at all locations within the tunnel.

d) Submit details of water treatment provisions to remove sediments, oil, grease, and other contaminants prior to disposal.

e) Submit a plan indicating disposal provision, discharge location(s), and discharge piping.

f) Data and Records: Continuous data monitoring of TBM performance shall be submitted to the Independent Engineer for information in real (instantaneous) time for the duration of TBM excavation. Data collection shall be accomplished by automatic electronic continuous recording systems. There shall be one dedicated data acquisition system per TBM to be installed in the Independent Engineer's main office for each TBM. Additionally, a duplicate data acquisition system shall be installed at the Clients Main Office. The data acquisition system supplied to the Independent Engineer's office shall allow the Independent Engineer to study and print out real time and historical data for the each TBM and guidance system via a dedicated computer.

g) Should the TBM guidance system not be part of the TBM data acquisition program an additional dedicated guidance system computer is required to duplicate the data acquisition system's scope. Alternatives which require the closure of the data acquisition program to view the guidance system are not acceptable although separate windows running the data/guidance programs simultaneously maybe acceptable, subject to the Independent Engineer's non-objection.

h) The data and guidance systems in each office shall be linked to the network printers at the corresponding Independent Engineer's office. Data to be collected shall include the following:

i. For every shove or stroke of TBM, the date, time and tunnel station at start of shove; duration of shove; type of soil and volume excavated both actual and theoretical; average drive motor current or hydraulic pressure; power consumption; thrust/propel cylinder pressure; number of operating motors; mode of operations and cutter head chamber pressure; tail void grout volumes and pressures

ii. Description of any delays longer than 15 minutes, water inflow, incidence of ground loss or other unusual events.

iii. Cutter and muck system component changes, including time and date of replacement, cutter position or number, and reason for changes.

iv. TBM orientation and deflection from line and grade, and other information provided by automatic data acquisition systems.

v. Records of deformation and/or damage to the lining elements

vi. Air quality reports – records of air and gas monitoring

vii. For a Slurry TBM, submit results of all quality control tests on the slurry for the previous day.

viii. For an EPBM submit results of all quality control tests on foam, polymers, bentonite and other soil conditioners for the previous day

### 3.8.5 Inspection and Testing

1. Where a New TBM proposed by the Concessionaire, the Independent Engineer shall be permitted to visit the TBM manufacturer's premises for the purposes of inspection and issuing no objection.
2. The Concessionaire shall be responsible for the quality of all materials used or present within the TBM and must ensure that all such materials used or present are adequate for the task they are to perform.
3. The Authority/Independent Engineer shall be permitted at any stage during manufacture of the TBM to inspect, examine and test on the manufacturer's premises the materials, workmanship and performance of all plant and components to be supplied under the Concession. Such inspections, examination or testing shall not release the Concessionaire from any of his obligations under the Concession.
4. New machines shall be assembled at the manufacturer's works on completion of fabrication and tested to demonstrate that all components operate correctly and in compliance to the Concession provisions herein. Site acceptance testing will also be required at the Site following delivery and assembly, prior to commencement of tunnel construction.

### 3.8.6 Personnel and Training

1) The Concessionaire shall submit qualifications and related experience of supervisory and TBM operation personnel including all Tunnel Supervisor, Lead Miner, TBM drivers, and surveyors for no objection by the Independent Engineer 60 days before construction.
2) The Concessionaire shall ensure that all key personnel who are responsible for driving, maintenance and controlling TBM have received the necessary training in the duties that they are required to perform and have appropriate experience and certified by the TBM manufacturer.
3) The Concessionaire shall provide and maintain a complete list of the names of persons, and their duties, responsible for TBM operation, who have completed the appropriate training by the TBM supplier to an acceptable standard. The details and experience of all key personnel for driving and controlling TBM shall be submitted to the Independent Engineer for obtaining a Notice to Proceed.

### 3.8.7 TBM CONSTRUCTION METHOD STATEMENT

Not less than 60 days before the Concessionaire intends commencing TBM excavation, he shall submit to the Independent Engineer for obtaining his Notice to Proceed, a detailed method statement, which shall include but not be limited to:

i. Methods of transportation and erection of the TBM;
ii. Method of commencing the tunnel drives, including details of the temporary thrust arrangements.
iii. Methods of determining ground conditions ahead of the face and methods of treating such conditions;
iv. Methods for dealing with water wells/borewells that may be intersected or influenced by the excavations;
v. Methods of functioning with the launch and retrieval shafts,
vi. Dismantling of the TBM;
vii. Operational details, including excavation, segment handling, ring selection/orientation control, ring building procedures, annulus and proof- drilling, grouting and control, alignment control, tunnel logistics, maintenance, slurry plant operation (STBM), effluent disposal, muck disposal, ground and spoil conditioning control (EPBM), interventions, changing cutters & picks and the like.
viii. Safety procedures, including compressed air working, cutter head entry, cutting tool changes, ventilation details, emergency evacuation procedures and the like.
ix. Details of the proposed monitoring and reporting systems.
x. Details of key personnel responsible for supervising, operating, maintaining and controlling the TBM.

### 3.8.8 TBM Spare Parts

1) The Concessionaire shall provide spare parts that are considered critical and long-lead items.

2) Storage of required spare parts shall be within Bangaluru and accessible to be brought to the Site within 24 hours.

3) The Concessionaire shall maintain an inventory of spare parts as recommended by the TBM manufacturer, to ensure continued operational availability of the TBM and all essential systems.

4) Spare part components for at least one TBM shall be the following minimum unless specified by the Independent Engineer:

   i. Main bearing and seals
   ii. Cutter head drive motors
   iii. Hydraulic pump for cutter head hydraulic drive motors
   iv. Set of complete full-face cutting tools (picks, cutters, disks) plus 50 percent additional spares should always be maintained.
   v. Screw conveyor for Earth Pressure Balance TBM
   vi. Segment erector bearing
   vii. Shield hydraulic thrust cylinder
   viii. Slurry pump for Slurry Face TBM
   ix. Shield articulation cylinder, pump and seals
   x. Tail seals
   xi. Earth pressure sensor
   xii. Screw conveyor pump for Earth Pressure Balance TBM

### 3.8.9 TBM Daily Record

The Concessionaire shall produce operational data for each Earth Pressure Balance Machine (EPBM) or Slurry Tunnel Boring Machine (STBM) throughout the whole tunnelling process in both hard and soft (electronic) copy for each working shift.

These shift reports shall be submitted to the Independent Engineer within 24 hours for Notice to Proceed and shall provide the following minimum information.

i. Start and finish time of the excavation stroke including all stoppages, recording the reasons for the stoppages.
ii. Ring number, chainage and key position.
iii. Start and finish time of the ring build including all stoppages, recording the reasons for the stoppages.
iv. All delays and the reasons for those delays during the shift.
v. Earth pressure readings at start, middle and end of excavation stroke for cutter chamber and screw-conveyor.
vi. Quantity of material excavated for each ring e.g. number of skips removed.
vii. Total advance for the shift and the accumulative advance.
viii. Number and location of any cutter bits/discs changed.
ix. Volume of grout injected per ring and the pressure, the accumulative volume of grout for the shift.
x. Volume, type and location of ground/spoil conditioning added per ring and the accumulative amount per shift with the concentration value.
xi. General comments on description of the excavated material.
xii. Quantity of tail grease consumed per ring.
xiii. Any segment damage on completed rings.
xiv. The timing and nature of any machine maintenance carried out.

### 3.8.10 TBM Daily Monitoring and Reporting

Not less than 60 days before the commencement of TBM excavation, the Concessionaire shall submit details of his proposed monitoring and reporting scheme to the Independent Engineer for Notice of No- objection. The content of this submission shall include, but not be limited to, the following:

i. Chainage of face at the start and end of each shift.

ii. Line and level of the tunnel rings erected during each shift, including details of any corrections made to the plane of the rings.

iii. Survey control data.

iv. Serial numbers of the segments erected, referenced against ring numbers and tunnel chainage;

v. Details of the geological conditions encountered during each shift, including details of any geological anomalies encountered;

vi. Operational data of the cutter-head drive, including torque and RPM;

vii. Thrust of propulsion rams;

viii. Operational data of slurry system (if applicable);

ix. Hours of operation of the TBM;

x. Details of any operational delays, including the TBM, backup and slurry systems (if applicable), recorded in 5-minute intervals;

xi. Details of any probing undertaken;

xii. Detailed cycle times for each ring, identifying the boring and erection times;

xiii. Details of any planned or unplanned maintenance carried out;

xiv. List of cutting tools replaced, their position and serial numbers;

xv. List of spare parts used;

xvi. Quantities and pressures used in the annulus grouting, with a reconciliation of the amount used;

xvii. Number and classification of supervisors and workmen engaged during each shift;

xviii. Any other information that the Independent Engineer may reasonably request.

## 3.9 SEGMENTAL LINING

### 3.9.1 General

1. The segments shall be designed to ensure that the full design life is achieved. In the case of pre-cast concrete linings special care shall be taken to ensure that corrosion of reinforcement or other cast in metal components does not affect the durability of the segments. Notwithstanding the requirements of the Specification, the design shall assume that the tunnel waterproofing measures will not be completely effective and therefore allowance shall be made for the effect of groundwater on any face of a segment.
2. Alternatively, purely Fibre Reinforced Segments or Hybrid (Rebars + Fibres) Segments shall be designed to ensure that the full design life is achieved.
3. To achieve full design life of concrete lining, impermeable concrete shall be produced and shall be tested in accordance with IS 3085 or DIN 1048. The ability of concrete to resist chloride ion penetration shall be tested in accordance with ASTM C-1202. Suitable property enhancers shall be used in appropriate % by weight of cement to ensure the protection of precast linings against corrosion of reinforcement.
4. The Concessionaire shall be entirely responsible for the design, manufacture and installation of the precast concrete tunnel lining segments for the bored tunnel. Manufacture shall be carried out in pre-casting facilities used solely for the production of precast units. The design and manufacture of the facilities and the control of production procedures shall be undertaken by experienced specialist personnel familiar with the manufacture of high strength, durable, dimensionally accurate precast concrete units.
   i. The segmental lining shall be a bolted lining built under the protection of the TBM's tail- skin.
   ii. The lining joints shall be watertight; caulking grooves and gasket recesses shall be provided. Elastomeric gaskets with appropriate configuration shall be provided to achieve the required water tightness and design life as stipulated in the Concession.

### 3.9.2 Casting Yard

Prior to the commencement the Concessionaire shall submit to the Independent Engineer for approval their design and logistics for the casting yard, including batching plant, storage facilities etc.

### 3.9.3 Submittals

The following submittals shall be made to the Independent Engineer for No-objection prior to commencement of segment manufacture;

1. Written confirmation from the Concessionaire and TBM Manufacturer of full and complete design coordination between the Concessionaire, TBM manufacturer, and the mould manufacturer. Include a written certification by manufacturers affirming the compatibility of total TBM system and back-up equipment with lining, segment erector, and backfill grout injection system.
2. Detailed layout of the Pre-cast yard showing location of manufacturing shed, batching plant, storage facilities, reinforcement yard, access and egress routes to and from the yard together with welfare facilities for the workers
3. Complete detailed design documentation for the no objection of the Independent Engineer which shall demonstrate the integrity of the design and compliance with design criteria at all stages including the design, manufacture, transport, storage, installation, operation, and inspection of the tunnel segments.
4. Documentation shall include design for segment lifting devices, grout/threaded lifting sockets, grout plugs, and reinforcing spacers and chairs. Concessionaire shall consider the overall stability of the assembled segmental rings and the individual segments in various loading combinations and provide details of the analysis to the Independent Engineer. The design shall confirm that the precast concrete segments are capable of sustaining without damage all temporary loads from segment handling, stacking, transportation, erection, secondary grouting, and TBM ram loads.
5. Detailed Design Drawings for the no-objection of the Independent Engineer shall include but not be limited to the following information.
   a) All segment types, layout, number of segments per ring, taper configuration, key configuration, concrete grade and type, packing, segment identification information, reinforcement, mechanical joint connection assemblies, dowels, bolts, connectors, guidance rods, gasket grooves, gaskets, grout/threaded lifting sockets and plugs, inserts, and accessories necessary for manufacture,

transportation, erection and performance of the lining system.

b) Key dimensions, spacing, and layout of the elements including plans, sections, elevations, and segment configurations for changes in alignment and grade.

c) Complete details of all the forms, including number of moulds, details for securing embedded items in place during casting, form geometry, and fabrication tolerances as previously described.

d) Details of the concrete mixes for the no objection of the Independent Engineer shall include but not be limited to the following information:

i. Constituents

ii. Water Tests

iii. Trial Mixes

iv. Results of tests on trial mixes.

a) Material specifications, properties and testing (and subsequent test results) for gaskets, packings and components of joint connection systems or assemblies, including pull-out capacity.

b) Concessionaire shall submit the following information to the Independent Engineer for non- objection prior to the commencement of segment manufacture:

i. Method Statement for Precast Concrete Segment Production

ii. Inspection Test Plan (ITP) for the Precast Concrete Segment Production

iii. Confirmation of compliance for materials with regard to materials, mixing, placing, curing, and storing of concrete constituents, concrete segments, and fixings

iv. Results of dimensional checks on segments and demonstration lining assemblies

v. Gasket performance testing results.

(1) Concessionaire shall submit Production Plan for no objection to the Independent Engineer prior to commencement of segment manufacture or applicable operations. Critical construction activities shall be identified and described, including points in the process where Independent Engineer review and comment are required before proceeding. The plan shall include the following:

(i) Detailed Work Plans, drawings, procedures and descriptions for fabricating, casting, curing, stripping, handling, transporting, storing, and fixing of gaskets. Information shall include:

a) Details showing layout of facilities for casting, curing and storing segments

b) Test methods to assess long term performance of gasket materials upon exposure to ground and groundwater constituents

c) Segment marking to be used, i.e., segment type, date cast, and serial number, including form identity

d) Segment repair and rejection criteria and procedures at the factory, on- site, and after installation

(ii) Production schedule for segment manufacture

(iii) Curing process for segment casting to 28 days after casting, including the following:

a) Test data establishing the strength gain and curing time relationship during the curing process

b) Methods to protect segments from direct sunlight and weather if stored outside

c) Measures to control shrinkage and temperature cracking of segments

d) Methods for testing (and subsequent test data) to confirm the consolidation and curing process will result in uncracked segments with the required strength and diffusion properties.

(iv) Name and location of a qualified, independent, testing laboratory for non- objection by Independent Engineer

(v) Methods to verify that the design strength of the segments has been attained prior to stripping.

(vi) Manufacturer product data, samples and certification of any materials or appurtenances used in manufacturing, handling, and assembly of the tunnel lining to include steel reinforcement, bolts, nuts washers, grouting materials, sealants, gaskets as well as any admixtures, retardant agents, curing compounds, bonding/repair materials, pozzolanic/cementitious materials, and steel fibres that will be used in the proposed concrete mix meet the Specification requirements.

(2) Concessionaire shall submit the assembly procedures, including sequencing of ring erection, bolting, adjusting, packing, jacking, and grouting, including details of installing segments for making alignment/grade corrections, tunnelling on curves, and integrating the segment lining with other support systems at shafts within 120 days before arrival of the TBM(s) for no objection by the Independent Engineer. The submittal shall include the following:

i. Methods to verify proper assembly during installation in tunnel

ii. Procedure and products for filling holes or pockets

No work shall start until the Independent Engineer has issued a no objection statement in writing.

### 3.9.4 Moulds

1) Moulds for the precast concrete segments shall be strongly constructed with smooth casting faces so that a true, sound surface of concrete is obtained. Joints shall be completely tight and close to prevent the escape of laitance from the concrete. All chamfer and radius strips, bolt hole formers and pockets, liners, cores, and all cast-in items shall be provided where required. Loose mould components which affect the integrity of the mould shall be clearly identified as being part of the main mould. The parts of one mould within a ring set shall not be interchanged with another. A marking system shall be adopted to ensure compliance with this requirement.

2) The design of the moulds to be used for all the pre-casting work shall receive a 'Notice to Proceed' from the Independent Engineer before any such moulds are manufactured.

3) The fabricator shall make a trial casting using the first set of moulds. The internal dimensions of the moulds shall be measured to 0.1mm before each trial pour. One trial unit shall be cast from each mould. The units shall be provided with a full reinforcement cage including radial joint reinforcement. As soon as possible after stripping from the moulds the segments shall be checked against the dimensions shown on the drawings.

4) During these trials, the segments are to be cured and stored in conditions equivalent to those to be used during works production. The segment dimension deviations shall be measured at 7, 28, and 90 days. Concurrent records of concrete temperatures, ambient humidity and any other relevant details shall be kept at these dates. No segment production shall be instituted until the tolerances shown on the drawings are achieved in the trials.

### 3.9.5 Segment Storage on Site

1) The Concessionaire shall establish a system of Site segment stock ordering, supply, and control which shall eliminate the possibility of tunnel construction stoppage due to lack of material.

2) The Concessionaire shall submit the methods of stacking and get no objection from the Independent Engineer.

3) The Concessionaire shall satisfy himself that segment design takes account of the method of delivery of the segments to the face, erection expedients, shove ram disposition, and other features of the TBM having an impact on the segments. The Concessionaire shall be responsible for ensuring a full ring of the lining is delivered to the TBM manufacturer, at no additional cost to the Authority, and at an appropriate time during the TBM manufacturing programme, to ensure compatibility with the TBM segment handling and erection systems.

4) The Concessionaire shall, for the duration of the tunnel drive(s), maintain a stock of fully cured (age >28 days) segments. These shall be sufficient for a minimum of 4 weeks construction at each location from which the Concessionaire may decide to supply material at the programmed rates of advance. During the closing stages of the tunnel drives these stocks shall be drawn down.

### 3.9.6 Trial Assembly

There shall be a trial assembly, before commencement of the bulk manufacture. This trial assembly shall consist of three rings bolted together on a horizontal plane platform to demonstrate compliance with this Specification of rings of each material and diameter. The rings shall be built one above the other with the cross joints offset by half a segment as appropriate. The fully bolted bottom ring shall be bolted to the platform or otherwise secured in position and shall be retained as a master ring until the completion of tunnel construction.

From time to time, as may be required or directed by the Independent Engineer and at no additional cost to the Concession, segments shall be built to form two rings on the master ring to ensure that tolerances and interchangeability of the segments are maintained. Adequate Notice of the trial assembly shall be given to the Independent Engineer to enable him to arrange inspection and checking of the assembly.

### 3.9.7 Marking of Segments

1) All tunnel segments delivered to site shall bear the indelible marks described below. Any segment which is delivered to site and upon which the markings cannot be read for whatever reason, shall not be used in the Works.

2) The markings must in no way compromise any requirement of this Specification, i.e. cover to reinforcement or waterproofing.

3) The following minimum information shall be included on the marking:

- Internal diameter
- Type of segment
- Mould Number
- Date of Casting

### 3.9.8 Transporting and Storing Segments

1) Segments shall be transported face up with timber spacers. When stored on site segments shall be stacked on edge, on a prepared level base with timber packing as necessary.

2) The method of lifting and handling, the type of equipment and method of transport shall not damage the segments.

3) Segments shall not be transported to site until they have achieved the 28 days compressive cube strength.

4) If the grout hole is to be used for segment handling, the Concessionaire shall ensure that this has been catered for in the design.

### 3.9.9 Joints

The faces of joints shall be cleaned before bolting segments. Bolts shall be tightened at the time of erection of each ring. For a shield drive the circle bolts shall be re-tightened prior to release of the shoving jack force.

### 3.9.10 Rolled Rings

Rings may be rolled to facilitate the construction of openings and may also be rolled to facilitate maintenance of the plane of the rings. Tapered rings shall be rolled as appropriate to achieve the specified alignments and gradients of the tunnels.

### 3.9.11 Bolts

The length of each bolt shall allow for two washers and two grommets and for all adjustments required in the alignment of the tunnels. When fitted in position the bolt threads shall be exposed for at least 3 mm clear of the nut.

### 3.9.12 Plane

1) Errors in the plane of a ring should be kept to a minimum. When they occur, the plane of the ring shall be adjusted by packing of maximum practicable continuous lengths of resilient, durable material which shall have received Notice to Proceed from Independent Engineer. Packing in a single joint shall not exceed 6 mm for concrete lining.

2) The packing shall be supplied in various thickness, as required, but not less than 2 mm, and when in place, shall be clear of the sealing strip.

3) In tunnel drives which utilise all tapered rings, packing shall not exceed 3 mm per circle joint.

### 3.9.13 Sealing Strips and Gaskets

1) All precast concrete lining segments shall have composite EPDM and Hydrophilic gasket inserted into recesses provided in all four mating surfaces of the individual segments. Notwithstanding this requirement the Concessionaire shall submit his gasket proposal to the Independent Engineer for his Non-objection

2) The size and position of the gasket shall be sufficient to take account of all tolerances for the segments and gaskets.

3) Immediately prior to the erection of a segment in the tail skin of the TBM each gasket shall be checked for anchorage to the segment, cleanliness and position.

### 3.9.14 Caulking Grooves

1) Caulking grooves shall be formed in segments in accordance with the design and this Specification to ensure that caulking to circle joints and radial joints may be made effectively continuous, the depth of caulked material in the joints being not less than 25 mm.

2) Prior to caulking all joints shall be inspected and thoroughly cleaned out as necessary. Any packing, grout or other foreign material projecting into the caulking space shall be cut out by an appropriate method.

3) Immediately prior to caulking, the joints shall be blown out with a compressed air as to remove any loose debris or water.

### 3.9.15 Grout Valves

Grout holes shall be provided in the tunnel lining for and necessary secondary grouting of the tunnel lining. These grout holes shall incorporate one-way valves to prevent ground and water loss during the grouting operation.

### 3.9.16 As-built Tolerances

1) The finished bored tunnel shall be of a minimum 13500 mm (exclusive of all as-build tolerances) internal diameter with respect to the designed/theoretical longitudinal axis of the tunnel. Notwithstanding the finished profile of the tunnel the segmental lining shall conform to the following structural tolerances;

   a) The maximum and minimum measured diameters in any one ring shall be within 40mm of the theoretical design diameter of the ring.

   b) Lipping: The lip between adjacent segments in a ring shall not exceed 5mm and shall not be so great as to prevent the connections between segments from being correctly installed, nor prevent the effective functioning of gaskets, nor reduce the face-to-face radial joint bearing area to an

extent where structural efficiency will be compromised

c) Stepping: The step between adjacent rings shall not exceed 10mm and shall not be so great as to prevent the connection between adjacent rings from being correctly installed, nor prevent the effective functioning of gaskets.

d) The plane of the leading face of each ring, including a taper ring, shall not depart at any point from the plane surface by more than 6 mm.

e) The roll of adjacent circle joint bolt holes shall not be greater than 5 mm or the tolerance in the bolt holes, whichever is smaller; the maximum total allowable bolt hole roll of any ring shall be controlled to be within limits as determined to achieve the overall construction tolerances and it shall not deviate from the relevant TBM roll excessively.

### 3.9.17 Non - Compliance with Tolerances

Where any part of the lining does not comply with the specified tolerances the Concessionaire shall submit to the Independent Engineer for Notice to Proceed, proposals for remedial or other measures to correct the defect or negate its effects as appropriate.

### 3.9.18 Damaged Segments

1) Any segments which are damaged or defective shall be indelibly marked and removed from the Site and replaced by the Concessionaire. Such damaged or defective segments shall be destroyed. No damaged or defective segments shall be used in the Works.

2) Rings which have been erected in the tunnel and are subsequently damaged may as a last alternative have to be removed and rebuilt. However, depending upon the nature and extend of the damage and impact on the durability of the segment the Concessionaire may propose remedial measures for rectification of the segment. No payment shall be made for defective segments until rectification has been given a No objection by the Independent Engineer.

3) Concessionaire shall submit to the Independent Engineer for no objection details of proposed tunnel lining repair processes to meet the design requirements of the project.

4) Concessionaire shall monitor all segment repairs for satisfactory performance of the repair and, if required by Independent Engineer, repeat or revise the repair process.

### 3.9.19 Grade of Concrete

The minimum grade of concrete shall be at least M60. The Concessionaire shall designate its grade of concrete as follows:

i. Concrete M60/20

ii. The letter M refers to the mix, the number 60 represents the characteristic compressive strength of 15 cm cubes at 28 days in MPa. M60 concrete thus has a characteristic strength of 60MPa. Other mix design will also be denoted in same way. The number 20 represents the nominal size of the aggregate in mm.

### 3.9.20 Tolerances

The dimensions of precast concrete segments shall be within the following tolerances:

a) Circumferential Length - 1mm

b) Thickness - 3mm

c) Width - 1mm

d) Internal diameter of completed ring - 0.2% internal diameter or 6mm whichever is the greater

e) Bolt holes size +1mm, -0.2mm

f) Bolt holes position 1mm

g) Width of gasket sealing groove - 1mm

h) Depth of gasket sealing groove +1mm, -0.5 mm

i) Mismatch of gasket sealing groove at corners <2mm

j) Steel templates specifically designed for the segments shall be provided to ensure the quality of the production of segments to the required tolerances.

## 3.10 Structural Concrete

### 3.10.1 General

(1) The Concessionaire shall establish a modern concrete laboratory with trained Independent Engineers, Quality Control (QC) Manager and technicians at the casting yard. The laboratory shall contain facilities for testing physical properties of cement, workability of concrete, cube strength, permeability, sieve analysis, RCPT, aggregate tests, tests required for mix design, chloride and sulphate tests of water and admixture, concrete temperature, oven, accelerated tests for cement/concrete strength, flexural strength of concrete etc. One room shall be air-conditioned to control temp and humidity for cement tests.

(2) All off-site material sampling and testing shall be done at laboratories accredited by NABL (National Accreditation Board of Testing and Calibration Laboratories) or internationally accredited laboratory to ISO 17025.

(3) The Concessionaire shall submit to the Independent Engineer full details and samples of all materials which he proposes to use for the manufacture of the precast tunnel lining at least 60 days before the commencement of manufacturing and obtain Notice to Proceed from the Independent Engineer. Any subsequent change in these materials, proposed by the Concessionaire shall not be permitted unless a Notice to Proceed has been obtained from the Independent Engineer.

(4) Polypropylene Fibers

PP Fibers shall conform to relevant International/National Standards or as instructed by Independent Engineer.

Micro Synthetic fibers may be required to be added to concrete to enhance structural durability and desired structural performance in case of fire. When such fibers are required, Concessionaire shall ensure that:

i. Micro synthetic fibers shall be CE certified (with Declaration of Performance certificate) in conformance to EN 14889-2.

ii. Fibers shall be dry and free from oil, grease and chlorides and shall be provided with arrangements to deliver anchorage properties. The fibers shall satisfy the following parameters:

a. Storage: Fibers shall be stored, handled and dosed in accordance with the manufacturer's recommendations. Generally, this will require them to be stored in dry, sealed containers until ready for use and shall be free from oil, grease, chlorides and deleterious materials which may reduce the efficiency of mixing or spraying processes, or which may reduce bond between the fibers and the concrete.

b. Fibers shall be dosed by automatic dosing system. Mixing procedure adopted by the Concessionaire should be such that there is no fiber balling.

Polypropylene fibers for reduction of spalling of final lining concrete in case of fire. Polypropylene Fibers (microfibers) shall be 100% polypropylene and conform to the requirement of European Standard EN14889-2 "Fibers for concrete – Part 2". Fibers shall have a round cross section with a diameter of 15 - 20μm and be slightly crimped. Fibers' length shall be minimum 6mm. The tensile strength of fibers shall be at least 400N/mm². The melting point shall be at 150 - 160 oC. Minimum 2 kg of PP microfibers to be added per cubic meter of lining concrete

### 3.10.2 Source of Materials:

1) All the sources of the materials shall require Independent Engineer Notice to Proceed in advance before bringing to the site. All materials for making concrete shall require Independent Engineer's Representative Notice to Proceed. A sample of material shall be deposited in the office of the Independent Engineer before placing orders for the materials with suppliers. The materials brought on to the works shall conform in every respect to their samples and specifications which have Notice to Proceed.

2) Fresh samples shall be deposited with Independent Engineer whenever type or source of any material changes. The Concessionaire shall check fresh consignment of materials as it is brought on to the works to ensure that they conform to the specifications.

3) The Independent Engineer shall have the option to have any of the materials tested to find whether they are in accordance with specifications at the Concessionaire 's expense. All bills, vouchers and test

certificates which in the opinion of the Independent Engineer are necessary to convince him as to the source and quality of materials or their suitability shall be produced for his inspection when required.

4) Any materials which have not been found to conform to the specifications and/or without Notice to Proceed by the Independent Engineer shall be rejected forthwith and shall be removed from the site by the Concessionaire at his own cost within the time stipulated by the Independent Engineer. The Independent Engineer shall have the powers to cause the Concessionaire s to purchase and use materials from any particular source, as may in his opinion, are necessary for the quality execution of work.

5) Concessionaire shall also ensure that all constituents of exposed concrete shall be taken from same sources to achieve a uniform colour and texture. Cement/blended cement/Cementitious material: They all will mean the same thing.

The cement or cementitious material used shall be of the following types:

i. 43 grade Ordinary Portland Cement conforming to IS: 8112.

ii. 53 grade Ordinary Portland Cement conforming to IS: 12269.

iii. PPC as per IS: 1489 (Part-I)

iv. PSC as per IS: 455

v. Fly ash as per IS: 3812 (Part I & II)

vi. Whenever possible all cements of each type shall be obtained from one constant source throughout the Concession, cement of different types shall not be mixed together. Different brands of cement, or the same brand of cement from different sources, shall not be used without Independent Engineer's Notice to Proceed.

Packaged cement shall be delivered to the site in original sealed bags which shall be labelled with the weight, name of manufacturer, brand and type. Cement received in torn bags shall not be used. Cement bags will not be handled with hooks which allow ingress of moisture.

Material which has become hardened or lumpy or fails to comply with the Specification in any way shall be removed from the site. Concessionaire may obtain cement in bulk and store it in suitable silos of adequate capacity. Each type of cement shall be stored in a separate silo and it shall be ensured, that cements of different quality are not mixed up.

All cement shall be fresh when delivered and at ambient atmospheric temperature. In fair faced elements, the cement used in the concrete for any complete element shall be from a single consignment. All cement for exposed concrete shall be from the same source and uniform in colour. With each and every delivery of cement the Concessionaire shall provide manufacturer's certificate that the cement conforms to the relevant Indian standard. The Concessionaire shall provide complete facilities at site for carrying out the following tests:

a. Setting time by Vicat's apparatus as per IS: 4031 and IS: 5513.

b. Compressive strength on cement as per IS: 4031, IS: 650, IS: 10080.

c. Total chloride content in cement shall in no case exceed 0.05 percent by mass of cement. Also, total sulphur content calculated as sulphuric anhydride (SO3), shall in no case exceed 2.5 percent and 3.0 percent when tri-calcium aluminate per cent by mass is greater than 5 or less than 10 respectively.

d. The cement will be blended with processed fly-ash conforming to IS specifications Cement and cement extenders shall be free flowing and free of lumps and shall be supplied in the manufacturer's sealed unbroken bags or in bulk. The temperature of the cement when added to the mixer shall not exceed 40° C unless otherwise agreed by the Independent Engineer.

All cement and cement extenders used in the Works shall be tested by the manufacturer or the Concessionaire in a laboratory which has Independent Engineer Notice to Proceed. Copies of all test results so obtained shall be delivered to the Independent Engineer before the cement and cement extenders are incorporated in concrete. All cement extenders used shall comply with the appropriate Indian standards for Fly Ash (FA) or Condensed Silica Fume (CSF) respectively as detailed above.

The Concessionaire shall keep full records of all data relevant to the manufacture, delivery, testing and use of all cement and cement extenders used in the Works and shall provide the Independent Engineer

with two copies thereof.

If the Concessionaire proposes to use a Type 1 Portland Cement, he shall only do so by blending it with a Noticed cement extender that has been issued Notice to Proceed by Independent Engineer.

Blending of Type 1 cement with an extender may be done, in the batch plant, or at a commercial blending plant.

Each set of tests carried out by the manufacturer or Concessionaire shall relate to not more than one day's output of each cement plant and shall be made on samples taken from cement which is subsequently delivered to the Site. Alternatively, the frequency of testing shall be one set of tests for every 200 tonnes of cement delivered to Site from each cement plant.

Cement and cement extenders which are older than 120 days from date of grinding shall be retested in a laboratory which has Independent Engineer Notice to proceed at the rate of one set of tests for every 200 tonnes or as otherwise directed by the Independent Engineer and at monthly intervals thereafter.

### 3.10.3 Aggregates

Aggregates from natural sources shall be in accordance with IS: 383. The Concessionaire shall submit to the Independent Engineer certificates of grading and compliance for all consignments of aggregate for Notice to Proceed. In addition, at site from time to time, the Concessionaire shall allow for carrying out such tests and for supplying test records to the Independent Engineer. Aggregates shall be produced by crushing, screening, washing and procured from sources only that have Independent Engineer Notice to Proceed.

For fair faced concrete, the Concessionaire shall ensure that aggregates are free from iron pyrites and impurities, which may cause discoloration. Aggregates shall be stored on paved areas in different compartments according to their nominal size.

**Fine Aggregate:**

The Concessionaire shall provide complete facilities at site for determining grading of aggregates by sieves as per IS: 383, IS: 460, IS: 1607, and IS: 2386.

Only the product of the secondary crusher will be acceptable, subject to conformity with IS: 383. To achieve an acceptable particle, shape the fine aggregate shall be manufactured using crushers specially adapted (Rollobar or similar) to suit the type of material available. Stone dust or grit from the stone quarries should not be considered as of acceptable quality.

It shall be free from clay, loam, earth or vegetable matter, salt or other harmful chemical impurities. It shall be clean, sharp, strong, angular and composed of hard siliceous material.

The fine aggregate shall be river sand, manufactured sand of appropriate grading. Sand dredged from sea; creeks will not be used. Sand shall be washed and screened to remove any organic matter and clay. RMC manufactured with sand dredged from sea/creek will not be used.

The grading of fine aggregate when determined as described in IS: 2386 (part I), shall be within the grading zones I, II, III.

The Concessionaire shall provide complete facilities at site for carrying out the following tests:

i. Proportion of clay, silt and fine dust by sedimentation method as per IS: 2386 part II.

ii. Moisture content in fine aggregate as per IS: 2386 Part III.

iii. Bulk density / Bulkage.

iv. Specific Gravity

**Coarse Aggregate:**

The coarse aggregate shall be crushed stone, natural gravel or a suitable combination thereof. Coarse aggregate obtained from crushed or broken stone shall be angular, hard, strong, dense, durable, clean and free from soft, friable, thin plate, elongated or flaky pieces and any deleterious material.

The grading of aggregate shall be controlled by obtaining the coarse aggregate in different sizes and blending them in correct proportions as and when required.

All coarse aggregate shall conform to IS: 383 and tests for conformity shall be carried out as per IS: 2386, Parts I to VIII.

The maximum size of coarse aggregate shall be such that the concrete can be placed without difficulty so as to surround all reinforcement thoroughly and fill the corners of formwork. Unless otherwise permitted by the Independent Engineer the nominal maximum size shall not exceed 40mm.

**Alkali reactive materials:**

The aggregates shall be evaluated to identify any minerals known to have a potential to cause alkali silica, alkali silicate, alkali carbonate or any other damaging chemical reaction between alkalis and aggregates. The minerals present should be determined in accordance with ASTM C294 and C295 on a range of samples selected to include every mineral type present in the aggregate as a whole irrespective of the proportion of the mineral.

The aggregate shall be kept clean at all times. The sand equivalent when tested in accordance with ASTM D2419 of the fine aggregate shall be greater than 80. The sand equivalent of the zero to 4.75 fractions of all aggregates shall be greater than 75.

Ethylene glycol tests shall be carried out by the Concessionaire.

Petrographic examination shall be carried out in accordance with ASTM or standard procedures to identify the minerals present and in particular the percentage of clay minerals.

**Chlorides:**

The chloride content shall not exceed 0.03% by mass expressed as chloride ion when tested in accordance with relevant standard.

**Sulphates:**

The Sulphate content shall not exceed 0.4% by mass expressed as SO3 when tested in accordance with relevant standard.

**Total Chloride and Sulphate Content:**

The total chloride content arising from all ingredients in a mix including cement, water and admixtures shall not exceed the flowing limits, expressed as chloride ion as a percentage of the mass of cement in the mix:

For reinforced concrete 0.1% in 95% of all test results providing no result is 0.25%. The total sulphate content expressed as SO3 of all the ingredients in a mix including cement, water and admixtures shall not exceed 4.0% of the mass of cement in the mix.

**Testing:**

**(a) Acceptance Testing:**

As soon as the first aggregates have been produced to stockpile the Concessionaire shall carry out tests. The method of sampling shall be in accordance with IS: 2430-1969. The amount of material required for each test shall be as specified in the relevant method of test given in IS: 2386 (Part I) – 1963 to IS: 2386 (Part VIII) – 1963.

All tests shall be carried out as described in IS: 2386 (Part I) – 1963 to IS: 2386 (Part VIII) – 1963.

If at any time a significant physical or chemical change in the nature of the coarse or fine aggregate occurs, or a new source of aggregate is used, the Independent Engineer may direct that some or all of the acceptance testing is repeated.

**(b) Routine Testing:**

The Concessionaire shall carry out routine testing of aggregates for compliance with the Specification during the period in which concrete is being produced for the Works. The tests set out below shall be performed on aggregates from each separate source on the basis of one set of tests for each day on which aggregates are delivered to the concrete batching plant provided that no set of tests shall represent more than 250 tonnes of fine aggregate nor more than 500 tonnes of coarse aggregate and provided also that the aggregates are of uniform quality. If the aggregate from any source is variable, the frequency of testing shall be as instructed by the Independent Engineer.

**Blending of aggregates:**

In order to obtain optimum workability, individual aggregates of nominal size 20mm, 10mm,

4.75mm and 2.36mm will be blended in such a way that the grading curve for all aggregates will be a smooth

curve from size 0.15mm to 40mm falling within the established envelop grading curve. Concessionaire shall establish envelop grading curve for each grade of concrete for given maximum size of aggregates for Notice to Proceed before finalising the mix design.

**Admixtures:**

Chemical admixtures are not to be used until Independent Engineer's Notice to Proceed. In case their use is permitted, the type, amount and method of use of any admixtures proposed by the Concessionaire shall be submitted to the Independent Engineer for Notice to Proceed. The minimum cement content specified shall not be reduced on account of the use of the Admixtures.

The Concessionaire shall further provide the following information concerning each admixture to the Independent Engineer:

i) Normal dosage and detrimental effects if any of under dosage and over dosage.

ii) The chemical names & solid contents of the main ingredients in the admixtures.

iii) The chloride content, if any, expressed as a percentage by weight of admixture.

iv) Whether or not the admixture leads to the entrainment of air when used in the manufacturer's recommended dosage.

v) Where two or more admixtures are proposed to be used in any one mix, the manufacturer's written confirmation of their compatibility.

In reinforced concrete, the chloride content of any admixture used shall not exceed 0.1 percent by weight of the admixture as determined in accordance with IS: 6925 and the total chloride and sulphate contents in concrete mix shall not exceed 0.10 and 4.0 percent respectively by weight of cement.

The admixtures when used shall conform to IS: 9103, ASTM C-494 or AASHTO M-154 or BS EN 934-2 and BS EN 480-10. The suitability of all admixtures shall be verified by trial mixes.

The addition of calcium chloride to concrete containing embedded metal will not be permitted under any circumstances.

Retarding admixtures when used shall be poly hydroxyl compounds or as Notice to Proceed by Independent Engineer.

Air-entering agents shall comply with ASTM C-260 or AASHTO M-194 or BS 5075. Each batch/ consignment shall be tested for specific gravity & performance in concrete before their use.

### 3.10.4 Batching Plants, Mixers and Vibrators:

(1) For all structural concreting work on the Project, the Concessionaire shall provide automatic weigh-batching plant of suitable capacity. The plant used shall conform to IS: 4925.

(2) The Concessionaire shall provide Concrete mixers (IS: 1791 – Batch type concrete mixers, IS: 2438 – Roller Pan Mixer) and Vibrators (IS: 2505 – Concrete Vibrators Immersion Type, IS: 2506 – Screed board concrete vibrators, IS: 4656 – Form Vibrators for Concrete) supplied by recognised manufacturers.

### 3.10.5 Mix Design and Workmanship

(1) It is the complete responsibility of the Concessionaire to design the concrete mixes by approved standard methods and to produce the required concrete conforming to the specifications and the strength, durability (fulfilling the requirements of DARR), workability requirements as required by the Specifications.

(2) The Mix Design for the segmental lining, once approved, shall not be altered without prior Notice to Proceed from the Independent Engineer. However, should the Concessionaire anticipate any change in quality of future supply of materials than that used for preliminary mix design, the Concessionaire shall inform the Independent Engineer in advance and bring fresh samples sufficiently in advance, to carry out fresh trial mixes. Design mix will indicate by means of graphs and curves etc., the extent of variation in the grading of aggregates which can be allowed. The S.D. and coefficient of variation shall be established for each grade of concrete. SQC graphs shall be submitted monthly.

### 3.10.6 Limits of Water and Cementitious Material Contents:

Maximum water / cementitious material ratio: For RCC members 0.40 Cement/blended cement / cementitious material Content: Cementitious material in concrete shall not be less than 380 kg/ cum for RCC work and 400 kg/ cum for PSC work under severe exposure. However, the quantity of cement (excluding Fly Ash) shall be limited to 450kg/ cum of concrete. Ordinary Portland cement (OPC) of 43 and 53 grade conforming to IS: 8112 and IS: 12269 respectively shall be used.

As regards trial mixes, acceptance criteria, acceptance specification, lot size, sampling and testing and sampling size for segments shall comply with the requirement of the relevant codes and standards.

### 3.10.7 Permeability Test for Concrete

Independent Engineer shall not give a Notice to Proceed without satisfactory test of Permeability by IS 3085 or DIN 1048 (Part – I) tests. Regular permeability tests shall be carried out as per frequency specified by relevant standards.

From the batches thus selected two concrete cylinders shall be made in accordance DIN 1048.

All cylinders shall be made, cured, stored, transported and tested in accordance with DIN-1048 Specifications. The tests shall be carried out in the site laboratory or off site laboratory.

At least two cylinders shall be made on each day's concreting until 60 cylinders have been made for each grade of concrete.

### 3.10.8 Acceptability Criteria:

**Rapid Chloride Penetration Test (RCPT)**

RCPT shall be carried out as per ASTM-C-1202 under controlled conditions and by trained technicians. The necessary equipment shall be installed at site laboratory or off-Site laboratory with Independent Engineer Notice to Proceed. The RCPT values should not be more than 1000 Coulombs.

### 3.10.9 Batching of Concrete Ingredients:

All concreting shall be either produced in automatic weigh batching plant installed at site or Ready-Mix Concrete manufactured in automatic weigh batching plant. The Concessionaire shall identify reputed RMC Manufacturers and submit to Independent Engineer for Notice to Proceed.

Batching Plant shall be properly maintained and calibrated at a regular interval. The frequency of the calibration shall be as specified by the relevant standards.

### 3.10.10 Placing temperatures:

During extreme hot weather, the concreting shall be done as per procedures set out in IS: 7861, Parts I & II. The concrete temperature shall not be more than 32oC at time of placing. In hot weather with temperature exceeding 40-degree C, the stock piles of fine and coarse aggregates for concreting shall be kept shaded from direct rays of sun and the concrete aggregates sprinkled with water for a sufficient time before concreting in order to ensure that the temperature of these ingredients is as low as possible prior to batching. The mixer and batching equipment shall be also shaded and if necessary painted white in order to keep their temperatures as low as possible. The placing temperature of concrete shall be as low as possible in warm weather and care shall be taken to protect freshly placed concrete from overheating by sunlight in the first few hours of its laying. The time of day selected for concreting shall also be chosen so as to minimise placing temperatures. In case of concreting in exceptionally hot weather the Concessionaire in his discretion specifies the use of ice either flaked and used directly in the mix or blocks used for chilling the mixing water from Chiller plant. In either case, the Concessionaire shall not be paid extra for cost of ice, additional labour involved in weighing and mixing etc. All salt and saw dust shall be removed from ice before use.

Quality of water used for making ice shall confirm to IS: 456. A complete record of concrete temperature shall be maintained and made available to Independent Engineer. The temperature shall be recorded both at the mixing & placing point.

### 3.10.11 Transporting, Placing, Compacting and Curing:

**General:**

Transporting, placing, compacting and curing of concrete shall be in accordance with IS: 456.

**Transporting:**

The mix after discharging from the mixer shall be transported by agitating transit mixers, buckets, pumps etc.

or as Independent Engineer Notice to Proceed without causing segregation and loss of cement slurry and without altering its desired properties with regard to water cement ratio, slump, air content, cohesion and homogeneity. It should be ensured that the concrete is moved to its final destination, placed and compacted before initial set.

The transportation is to be done by agitating transit mixers, pumps or other approved methods.

**Placing:**

The method of placing shall be such as to prevent formation of cold joints, adulteration, segregation or loss of ingredients. The thickness of horizontal layers shall not exceed 300mm. High velocity discharge of concrete causing segregation of mix shall be avoided. The concrete shall be placed in the forms gently and not dropped from a height exceeding 1.5m. Each layer of concrete shall be compacted fully before the succeeding layer is placed and separate batches shall follow each other so closely that the succeeding layer shall be placed and fully compacted before the layer immediately below has taken initial set.

Concreting of any portion or section of the work shall be carried out in one continuous operation and no interruption of concreting work will be allowed.

**Compaction**

Concrete shall be fully compacted by Noticed means during and immediately after placing. It shall be thoroughly worked against the formwork, around reinforcement and embedded fittings without displacing or distorting them, and into corners, in order to form a solid mass free from voids.

The concrete shall be free from honeycombing and planes of weakness.

Concrete shall not be subjected to disturbances by vibration within 4 to 24 hours after compaction. Concrete can be compacted by means of external vibrators and in exceptional cases, by internal vibrators. For external vibration, the design of the segment moulds and positioning of vibrators shall be such that efficient compaction and avoidance of surface blemishes is ensured. Internal vibrators shall be rubber tipped and be capable of producing not less than 10,000 cycles per minute.

The Concessionaire shall ensure that vibrators are operated at pressures or voltages not less than those recommended by the manufacturer in order that the compactive effort is not reduced. Vibration shall be applied by experienced operators only, who shall be under the direct supervision of an experienced concrete supervisor at all times. Sufficient standby vibrators shall be held available for immediate use in case of breakdowns. A sufficient number of vibrators shall be operated to enable the entire quantity of concrete being placed to be vibrated for the necessary period and, in addition, standby vibrators shall be available for instant use at each place where concrete is being placed.

Internal vibrators shall be inserted vertically into the concrete to penetrate the layer underneath at regular spacing which shall not exceed the distance from the vibrator over which vibration is visibly effective and, in any case, shall not exceed 600 mm.

Internal vibration shall not be applied by way of reinforcement nor shall vibrators be allowed to touch formwork or reinforcement, or other embedded items as far as is practicable.

Special attention shall be given to the compaction of concrete behind embedded items and in all places where high concentrations of reinforcing steel occur.

The concrete shall be compacted by use of appropriate diameter vibrator by holding the vibrator in position until:

i. Air bubbles cease to come to surface.

ii. Resumption of steady frequency of vibrator after the initial short period of drop in the frequency, when the vibrator is first inserted.

iii. The tone of the vibrated concrete becomes uniform.

iv. Flattened, glistening surface, with coarse aggregates particles blended into it appears on the surface.

v. To secure even and dense surfaces free from aggregate pockets, vibration shall be supplemented by tamping or tamping by rods in the corners of forms and along the form surfaces while the concrete is plastic.

vi. A sufficient number of spare vibrators shall be kept readily accessible to the place of deposition of

concrete to assure adequate vibration in case of breakdown of those in use.

vii. Form vibrators whenever used shall be clamped to the sides of formwork and shall be positioned such that the efficient compaction and avoidance of surface blemishes is ensured. The formwork must be made specially strong and watertight where this type of vibrator is used. Care must be taken to guard against over vibration especially where the workability of the concrete mix is high since this will encourage segregation of the concrete.

### 3.10.12 Curing

1) Segments shall not be de-moulded until the concrete has achieved sufficient strength to prevent damage to the segments during the de-moulding process.

2) Secondary curing of segments is to be initiated immediately following initial stripping of the moulds. The segments are to be maintained for 7 days at a minimum of 100 % humidity, under cover prior to stacking and placing in the stockpile.

3) Curing of concrete shall be complete and continuous using potable water, free from chlorides and sulphates and other requirements as stated in IS 456.

4) Immediately after compaction and completion of any surface finishes the Concessionaire shall protect the segment from the evaporation of moisture by means of polythene sheet, wet Hessian or other material kept soaked by spraying. As soon as the concrete has attained a degree of hardening sufficient to withstand surface damage, moist curing shall be implemented and maintained for a period of at least 21 days after casting.

5) Method of curing and their duration shall be such that the concrete will have satisfactory durability and strength and members will suffer a minimum distortion, be free from excessive efflorescence and will not cause undue cracking in the works by shrinkage.

6) Steam curing with approved methodology may be adopted if required.

7) Curing compounds may be permitted with Independent Engineer's Notice to Proceed. However, it is required to be proved that using curing compound the concrete shall not have less strength than concrete cured by water curing. It shall not leave any discolouration on the structural concrete and should not be detrimental to durability of concrete.

### 3.10.13 Handling and Storage:

The precast units shall be stored under cover prior to stacking and placing in the stockpile. The area intended for the storage of precast units should be surfaced in such a way that no unequal settlement can occur.

To prevent deformation of slender units, they should be provided with supports at fairly close intervals and should also be safeguarded against tilting. Lifting and handling positions should conform to the requirements. In addition, location and orientation marks should be put on the members, as and where necessary. During erection the precast units should be protected against damage caused by local crushing and chafing effects of lifting and transport equipment

### 3.10.14 Cracks

Cracks, which in the opinion of the Independent Engineer may be detrimental to the stability, strength, durability or structural integrity of the works, the Concessionaire, at no additional cost to the Concession shall perform sufficient tests as necessary and furnish an Independent Engineer with a report. On evaluation of the report, the Independent Engineer may request remedial works to be taken. Any remedial works shall be at no additional cost to the Concession.

### 3.10.15 Defective Concrete Segments

Precast concrete segments damaged by improper curing, stripping, storage, handling or any other cause or any which are honeycombed, homogeneous, dimensionally incorrect, or have surface finish or feature defects outside those required by these Specifications, may be classed as defective shall not be used in the Works. All defective segments shall be at no additional cost to the Authority.

The decision of Independent Engineer in this regard shall be binding on the Concessionaire. Repair of defects:

If on stripping the precast segment moulds the concrete surface is found to be defective in any way, the Concessionaire shall make no attempt to remedy such defects prior to inspection and the receipt from Concessionaire Quality Department.

### 3.10.16 Concrete Finishes

The surface of concrete on which forms had been fixed while concreting shall be classified as follows:

**Formed Surface:** Allowable deviation from plumb or level dimensions shown on the drawings and from the alignment profile, grades and is defined as "tolerance" and is to be distinguished from irregularities in finishes as described herein. Tolerances in concrete construction are specified elsewhere.

The classes of finish and requirements for finishing of concrete surface shall be as shown on the drawings or as hereinafter specified.

Completed concrete surface shall be tested, where necessary to determine whether surface irregularities are within the limits specified hereinafter.

Surface irregularities are classified as "Abrupt" or "Gradual". Offsets caused by displaced or misplaced form sheathing, or form sections or by loose knots or otherwise defective timber form will be considered as abrupt irregularities and shall be tested by direct measurements. All other irregularities shall be considered as gradual irregularities and will be tested by use of template, consisting of a straight edge or the equivalent thereof for curved surfaces. The length of the template shall be 150cm for testing of formed surfaces and 300cm for testing of unformed surfaces.

The classes of finish for formed concrete surfaces are designated by one of the symbols F1, F2, F3 and F4. Unless otherwise specified or indicated on drawings, these classes of finish shall apply as follows:

**Finish F1:** This finish applies to surfaces where roughness is not objectionable, or surface that will otherwise be permanently concealed. Surface treatment shall be the repair of defective concrete, correction of surface depressions deeper than 25 mm and filling of tie rod holes. Form sheathing will not leak mortar when concrete is vibrated. Forms may be manufactured with a minimum of refinement.

**Finish F2:** This finish is required on surfaces permanently but not prominently exposed to public view for which other finishes are not specified except F1. Forms shall be manufactured in a workmanlike manner to the required offsets or bulges. Surface irregularities shall not exceed 5mm for abrupt and 8mm for gradual irregularities measured with a 1.5m template.

**Finish F3**: This finish is required for coarse textured concrete surfaces intended to receive plaster, stucco or wainscoting. Surface irregularities shall not exceed 5mm for both abrupt and gradual irregularities.

**Finish F4**: This finish is designated for surfaces prominently exposed to public view where appearance is also of special importance. This shall include decorative features on the building structures and retaining structure supporting the ramp embankment. To meet with requirements for F4 finish, forms shall be manufactured in a skilful, workmanlike manner, accurately to dimensions. There should be no visible offsets, bulges or misalignment of concrete. Abrupt and gradual irregularities shall not exceed 3mm. Irregularities exceeding this limit shall be reduced by grinding to a level of 1:20 ratio of height to length. Jute bag subbing or sand blasting shall not be used.

**Unformed Surfaces:**

The classes of finish for unformed surfaces are designated by symbols U1, U2, U3 and U4. Unless otherwise specified or indicated on drawings, these classes of finish shall apply as follows:

**Finish U1**: This finish applies to unformed surfaces that will be concealed permanently or otherwise where a screeded surface finish meets the functional requirements. Finish U1 is also used as the stage of finishes for U2 and U3. Finishing operations shall consist of sufficient levelling and screeding to produce an even uniform surface. Surface irregularities shall not exceed 10mm.

**Finish U2:** This is floated finish, and used on all outdoor, unformed surfaces. Finish U2 is also used as the second stage of finish for U3. Floating to be performed manually or mechanically on stiffened screed surface shall be minimum to produce textured surface. If finish U3 is to be applied, floating shall be continued till a small amount of mortar without excess water is brought to the surfaces so as to permit effective trowelling. Surface irregularities shall be removed as directed by the Independent Engineer.

**Finish U3**: This is a trowelled finish and shall be used for tops of parapets, etc prominently exposed to view. When the floated surface has hardened sufficiently, steel trowelling shall be started. Steel trowelling on hardened, floated surface shall be performed with firm pressure to produce a dense uniform surface free from blemishes and trowel marks and having slightly glossy appearance. Surface irregularities shall not exceed 5mm.

**Finish U4**: This is a steel-trowelled finish, similar to finish U3, except that light surface pitting and light trowel marks such as obtained from the use of machine trowelling will be acceptable, provided that surface irregularities do not exceed the limits specified for finish U3.

### 3.7.16.1 Exposed Concrete Work

Exposed concrete surfaces shall be smooth and even originally as stripped without any finishing or rendering. The Concessionaire shall exercise special care and supervision of formwork and concreting to ensure that the cast members are made true to their sizes, shapes and positions and to produce the surface patterns desired. No honeycombing shall be allowed. Concessionaire shall ensure that no air bubbles are formed on the exposed surface. Concrete pouring sequence, vibration methodology etc. shall be planned to avoid air bubbles.

### 3.7.16.2 Age of Concrete at Removal of Formwork

Age of Concrete at Removal of Formworks shall be in accordance with CPWD Specifications 96 or IS: 456. The Independent Engineer may vary the periods specified if he considers it necessary. Immediately after the forms are removed, they shall be cleaned with a jet of water and a soft brush.

### 3.7.16.3 Stripping of Formwork

The work of form work removal should be planned, and a definite scheme of operation worked out. Formwork shall be removed carefully without jarring the concrete and curing of the concrete shall be commenced immediately. Concrete surfaces to be exposed shall, where required be rubbed down with Carborundum stone or bush-hammer to obtain a smooth and even finish. No extra charge will be allowed to the Concessionaire for such work on concrete surfaces after removal of forms

## 3.11 Reinforcement

Any steel specified for reinforcement shall conform in every respect to the latest relevant Indian Standard Specifications and shall be of tested quality under the ISI Certification Scheme. All reinforcement work shall be executed in conformity with the drawings and carried out in accordance with the relevant Indian Standard Specifications IS: 2502- Bending and Fixing of Bars for Concrete Reinforcement. The reinforcement steel shall be from primary producers and not re-rolled steel shall be supplied

### 3.11.1 Storage:

Reinforcement shall be clearly labelled and stored on Site either in racks or on a hard- impermeable base so that it remains straight and free from contamination.

Any reinforcement which is likely to remain in storage for a long period shall be protected from the weather so as to avoid corrosion and pitting. All reinforcement which has become corroded or pitted to an extent, which, in the opinion of the Independent Engineer will affect its properties, shall be removed from Site without delay.

### 3.11.2 Cutting and bending:

No flame cutting of high-tensile steel bars shall be permitted. Except as provided for below, all bars shall be bent cold and bending shall be done slowly, a steady, even pressure being used without jerk or impact. Reinforcing bars that have been bent shall not be re-bent at the location of the original bend without Independent Engineer Notice to Proceed.

### 3.11.3 Surface condition:

Immediately before the concrete is placed around the reinforcement, the reinforcement shall be clean, free from mud, oil, grease, paint, loose rust, loose mill scale or any other substance that can have an adverse effect on the steel or concrete or reduce the bond.

### 3.11.4 Inspection & Testing

Every bar shall be inspected by Concessionaire before assembling on the Works and any defective, brittle, rusted or burnt bars shall be removed. Cracked ends of bars shall be cut out.

Reinforcement steel shall be fresh, free from corrosion. Corroded steel will not be incorporated in work. If there are traces of corrosion, then the Concessionaire must give the following treatment to steel for which nothing extra shall be paid. Cleaning of steel by wire brush for removal of dust and rust. No work shall be commenced without the Independent Engineer Notice to Proceed of design drawings. Manufacturer's Certificate shall be supplied for each lot of supply.

Specimens sufficient for three Tensile Tests for each different size of bar for each consignment delivered shall be sampled and tested by the Concessionaire. Batches shall be rejected if the average results of each batch are not in accordance with the specifications and shall be removed from Site, without delay.

All manufacturer's test certificates, batch reference labels and quality control certificates shall be retained by the Concessionaire and noted against each bar mark number at the time of cutting and bending. This information shall be copied to the Independent Engineer weekly.

### 3.11.5 Bar Bending and Bar Bending Schedule

All bars will be carefully and accurately bent by approved means in accordance with IS: 2502, and relevant drawings. It shall be ensured that depth of crank is correct as per the bar cutting and bending schedule and bent bars are not straightened for use in any manner that will injure the material. Prior to starting bar bending work, the Concessionaire shall prepare bar bending schedule from the structural drawings supplied to him and get Independent Engineer

Notice to Proceed. Any discrepancies and inaccuracies found by the Concessionaire in the drawings shall be immediately reported to the Independent Engineer whose interpretation and decision there to, shall be accepted.

### 3.11.6 Lapping & Welding

As far as possible, bars of the maximum length available shall be used. Laps shown on drawings will be based on the use by the Concessionaire of bars of maximum length. Payment for reinforcement shall be made only for reinforcement shown in such drawings and such laps. In case the Concessionaire wishes to use shorter bars, laps shall be provided at the Concessionaire 's cost in the manner and at the locations that the Independent Engineer Notice to Proceed.

Bars having butt or lap welds shall be provided as specified in the drawings or as Independent Engineer Notice to Proceed.

Mechanical couplings shall be made only by the methods specified and at the positions shown on the Drawings.

### 3.11.7 Spacing, Supporting and Cleaning

Bars may be welded by Noticed electrical process which does not affect the tensile properties of the bar. Alternatively, the bars shall be bound together with No. 16 gauge, soft annealed wire at sufficient intersections to ensure that the network of bars will retain its designed form, and the network shall be temporarily supported so as to retain its correct position during the process of placing and compacting the concrete. The ends of all such tying wires shall be carefully turned into the body of the concrete and clear of the mould.

Top reinforcement shall be supported on adequate stools to ensure that the reinforcing bars are firmly held in position during concreting.

Normal stools and supports will be detailed on the Drawings and bending schedules. The Concessionaire shall provide for any additional supporting steelwork to suit his arrangements.

Reinforcement shall be rigidly fixed so that no movement can occur during concrete placing. Any fixings made to the formwork shall not be within the space to be occupied by the concrete being placed.

Cover and spacer blocks required to support the reinforcement shall be as small as possible consistent with their use and be of Noticed design and material.

Projecting ends of ties or clips shall not encroach into the concrete cover.

Cover:

The term "cover" in this context shall mean the minimum clear thickness of concrete between the surface of the reinforcement and face of the concrete.

The minimum cover to reinforcement shall be 40 mm. Cover blocks or spacers required for ensuring that the specified cover is obtained shall be of a material, design and same colour, strength and material source as the surrounding concrete. The blocks shall be formed in specially manufactured moulds and the concrete compacted on a table vibrator, all with Notice to Proceed from Independent Engineer.

The blocks shall be cured in water for at least 7 days. The Concessionaire shall measure the cover to all reinforcement with a cover meter as soon as the formwork has been stripped and submit the record of this

survey to the Independent Engineer as soon as practical. Precast concrete segments with inadequate cover shall be rejected and removed from Site without delay.

### 3.11.8 Welding

Wherever specified all lap and butt welding of bars shall be carried in accordance with IS: 2571. Only qualified welders shall be permitted to carry out such welding. For cold twisted reinforcement welding operations must be controlled to prevent a supply of large amounts of heat larger than that can be dissipated. The extreme non-twisted end portion shall be cut off before welding. Electrodes with rutile coating should be used. Bars shall be free from rust at the joints to be welded. Slag produced in welding after alternative run should be chipped and removed by brush. Electrode should not be lighted by touching the hot bar. Concessionaire shall submit welding procedure for Independent Engineer Notice to proceed. All test certificates shall be made to prove the soundness of the welded connection to the Independent Engineer.

### 3.11.9 Production Tests

This Section covers tests which are to be carried out at the preproduction stage only. Regular testing during full production shall be carried out in accordance with the Specification.

The tests have been classified in terms of the level of compliance required:

- Compliance Tests - Tests to prove that the concrete satisfies an existing requirement.
- Preproduction Trials - Tests to establish the criteria which will be used during production.
- Reference Tests - Tests which provide information for design or for long-term confirmation of the more rapid tests.

The following sections list the tests and their form and gives reasons for their inclusion. The numbers of tests and frequency of sampling are summarized below.

Compliance tests:

**(a) On aggregates:** Wet sieve analysis

10 % fines values Flakiness –

Flakiness index of coarse aggregates which shall be as follows:

For class 1, 2, and 3 aggregates: not more than 35

For class 4 aggregate: not more than 40

Aggregate chloride content: The chloride content of any aggregate used shall not exceed

0.03 % by mass expressed as chloride ion;

Petrography: Petrographic examination shall be carried out in accordance with ASTM or standard procedures to identify the minerals present and in particular the percentage of clay minerals.

The petrography tests, because of the specialist knowledge required in the analysis, shall only be carried out at an external laboratory which has Independent Engineer Notice to Proceed. The main purpose is to compare the structure of the aggregate as delivered to that of samples from the quarry which was tested previously.

**(b) On hardened concrete:**

Concrete strength - Standard cube crushing methods to establish 28 day strength and correlation with 3 day and 7 day strength. Standard and match curing as for production segments will be used to determine the correlation between the two.

**Preproduction Trials:**

(a) On aggregates:

Moisture content

(b) On fresh concrete:

Veebee - To develop a target range of times and assess the controllability of workability

(c) On hardened concrete:

Schmidt hammers - To calibrate for possible use as comparative NDT during production.

Weighing of samples - Cubes and cores to establish density

(d) Curing trials:

Temperature monitoring - Segments and cubes shall be instrumented with thermocouples to monitor temperatures during curing. Monitoring shall continue after demoulding to establish the optimum type and period of curing to avoid thermal shock and rapid drying out

Inspection for cracking - For the various cooling regimes visual inspection (by wetting the concrete) for cracking and inspection of cores taken from the segment will be made.

(e) Durability tests:

Water permeability tests

**Reference tests:**

(a) Design parameters:

E value test

Creep test (on a 90-day cylinder).

Thermal expansion coefficient - for use in design and monitoring of linings Drying shrinkage/wetting expansion (on cores)

Concrete compressive strength - relationships between 28 day and 90 day cube strengths and between cube and cylinder strengths

Concrete tensile strengths - cylinder splitting tests for input to design and interpretation of joint tests. The cylinders shall be accelerated cured in the same manner as the segments before being put into a curing tank.

(b) Durability:

Standard absorption test Water Permeability Summary of tests

## 3.12 Tolerances and Inspections

1) The tunnel lining segments shall be cast to the dimensions shown on the Concessionaire 's non-objected drawings and within the tolerances specified. Segments shall be cast with such accuracy and uniformity of dimensions that all similar segments shall be interchangeable with corresponding segments of other rings.

2) A comprehensive quality control and inspection procedure shall be instituted by the Concessionaire. The Concessionaire shall be responsible for the production of segments of the required quality and accuracy and, in addition, shall institute an appropriate inspection regime for quality control.

3) Templates, gauges and testing apparatus as required for quality control shall be provided and kept suitably protected from damage and distortion and free from dirt and corrosion, ready for use in checking the segments as required. The segments shall be checked for dimensional accuracy using a measuring method no objected by the Independent Engineer. The method of checking shall be included in the segmental lining manufacturing method statement.

4) The first segment cast in any mould shall be gauged. Thereafter 5 per cent of the segments shall be gauged. Further, the number of segments gauged shall, whenever any variation in quality has occurred, be that required to establish the accuracy and consistency of production as quickly as possible.

5) A record shall be kept of the units cast in each mould and any mould that becomes distorted or which casts faulty units shall be withdrawn from service. A fully detailed record of the result for each measured segment shall be made available within 24 hours of the verification.

## 3.13 Elastomeric Gaskets

1) The gasket shall be capable of providing a watertight seal under all combinations of specified tolerances associated with manufacturing and ring erection. Gaskets shall be dense, elastomeric synthetic rubber and shall be supplied from approved manufacturers and shall be tested in the presence of the Independent Engineer.

2) The test rig shall simulate a range of conditions of displacement and joint gap, including the worst combination to be encountered in the completed structure. In each test the water pressure shall be

increased in increments of 0.5 bar and held at each value for 15 minutes. The final pressure shall be at least 1 bar in excess of the maximum hydrostatic pressure to which the tunnel structure may be subjected. This pressure shall be maintained for 24 hours during which no leakage shall occur at the gasket interface. Tests shall be carried out at normal ambient temperature.

3) Gaskets shall be manufactured to fit the groove preformed in the segment. Prototype gaskets shall be fit-tested to assess stretch characteristics.

4) The material from which the gaskets are to be manufactured shall withstand any aggressive response from the ground or groundwater. In particular the gasket material shall withstand chemical attack and biological degradation such that the gasket functions properly for the design life of the facility.

5) Elastomeric gaskets shall comply with the requirements of BS 774, BS EN 681 and BS EN 682. The material shall consist of a compound based on EPDM able to withstand the long-term stresses and strains without detriment to the specified performance.

6) The gasket cross section shall be dimensioned to suit the groove as detailed in the non-objected design drawings for the mating faces of the segmental tunnel linings. Manufacturing tolerances shall be ±1 mm for width and ±0.5 mm for thickness.

7) Gaskets shall be manufactured from extruded solid sections with appropriate spaces within the section to enable the gasket to be fully compressible within the groove formed in the concrete segments. The gasket shall still be capable of further compression when its top surface is level with the groove.

8) The extruded section shall be joined to form a rectangular gasket that is a stretch fit into the grooves of the segments. The corner joint shall be shot moulded and the corner pieces shall be of different section from the extruded lengths in order that the water-tightness characteristics described in the specification may be achieved and to avoid excessive load on the corners of the concrete segments.

9) Gaskets shall be fitted into the groove cast in the segmental tunnel linings prior to erection. The adhesive used shall be as recommended by the gasket manufacturer with a 'Notice to Proceed' from the Independent Engineer.

10) The Concessionaire shall submit to the Independent Engineer full details and samples of the gaskets which he proposes to use at least 60 days before the commencement of segment manufacturing.

## 3.14 Bolts and Grommets

### 3.14.1 Bolts

Radial and circumferential joint bolts shall be made from steel grade 8.8 to BS 5950 and BS 4921. and has a 'Notice to Proceed' from the Independent Engineer.

### 3.14.2 Grommets

Grommets shall be plastic and to a specification that has a 'Notice to Proceed' from the Independent Engineer.

### 3.14.3 Packings

Stress distribution packings for radial and circumferential joints shall be specified and shall be cut from an approved bituminous felt fibre-based sheet or marine hardboard to a minimum thickness of 2 mm. Timber packings that may be required for the correction of the plane of the ring shall be marine hardboard or plywood, sawn to shape with boltholes. They shall be treated to retard rot and fire and shall be available in all necessary thicknesses as may be required to suit the tapered ring.

## 3.15 GROUTING

### 3.15.1 General

1) A grouting system shall be provided on the TBM which shall be designed to inject grout continuously into the void behind the tail shield as it advances. This system shall be kept piped up to the tail shield ports but have the facility for emptying the pipes and washing them when not in use.

2) The system shall be capable of automatic operation linked to the advance of the TBM. The system should have the facility for selectable volume and pressure control and should be sized to suit the anticipated tail shield void and the annulus between the excavated surface and the extrados of the segmental lining.

3) Control and monitoring of grout injection volumes and pressures shall be possible on the operator's

control panel and at the grouting station within the backup of the TBM and the results shall be recorded in the data logger.

4) Primary grouting is the annulus grouting which is applied immediately after lining has been built.

5) Secondary grouting is done subsequent to the primary grouting and the purpose of which is to ensure that all cavities behind the segmental lining not filled by primary grouting operations are completely filled.

6) The grout mix design shall require a Notice to Proceed from the Independent Engineer before use.

### 3.15.2 Secondary Grouting

Secondary grouting of the segmental lining shall be done within 14 days of undertaking primary grouting at that location and preferably at a time when the tunnel face is at a distance between 30m to 100m from the proposed secondary grouting location.

### 3.15.3 Concessionaire 's Submission

Prior to commencing any grouting operations, the Concessionaire shall submit the following to the Independent Engineer for no objection at least 6 weeks prior to commencement of any planned grouting operations:

1) Verification of qualifications as specified herein.

2) Details of grout mix proportions – admixtures, including manufacturer's literature, and laboratory test data verifying the strength of the proposed grout mix.

3) Pressure gauge calibrations.

4) A method statement for no objection of the Independent Engineer. Separate method statements shall be provided for each type of grouting. The method statement shall include descriptions of all equipment used to mix and pump grout, mix designs, pumping rates and pressures, injection points, methods of monitoring, and recording and controlling grouting activities.

5) Submit the following to the Independent Engineer for information during construction at the times indicated:

   (1) Grout Logs: Within 1 working day of grouting submit field logs containing as a minimum the following:

      i. Description of injection points using stationing along tunnel and degrees clockwise looking up station from the crown.

      ii. Volume of grout take at each injection point.

      iii. Maximum sustained pressure at each injection point

      iv. Grout time for each hole from the beginning to end of each injection

      v. Grout mix pumped.

   (2) Certification and Test Results: Documentation and results from the testing laboratory:

      i. Materials used in the grout are free from metallic components and corrosion- producing elements.

      ii. Materials meet specified shrinkage and compressive strength requirements

      iii. Results of all tests specified herein.

   (3) Reports and Records: Maintain and submit daily logs of grouting operations including pressures, volumes, and grout mix pumped, and time of pumping.

### 3.15.4 Quality Control

1) All grouting operations are to be performed in the presence of the Independent Engineers representative, unless an emergency develops that requires cavity grouting to stabilize the ground around a tunnel, shaft or other underground structure. Notify the Independent Engineer at least 24 hours in advance of starting grouting operations.

2) Perform all work in accordance with the approved method statement and all current applicable

regulations and codes. In the event of a conflict, comply with the most restrictive applicable requirement.

3) The properties of the grout shall be determined by the mix design and the specific end use of the grout.

4) Record Requirements:

5) Monitoring: Maintain for each batch, or if mixed continuously, a continuous record of grout mix preparation including water/cement ratio, flow, bleed, specific gravity and the proportion of cement, fly ash, sand, water, admixtures, and other constituents.

6) Field Logs: Maintain field logs of the volume and pressure of grout injected at each injection point. Maintain logs of the sequence used to grout each location and each point.

7) Retain a full-time, on site Grouting Manager with at least 10 years of related work experience on similar projects to manage the grouting program by designing, testing, and overseeing the injection of grout mixes of the type required.

### 3.15.5 Grouting Materials

1) Cement used for annular grouting shall be Type II or Type V Portland cement.

2) Water: All water used in preparing grout shall be potable, clean, and free from sewage, oil, acid, alkali, chlorides, salts, organic materials, and other impurities.

3) Bentonite shall conform to BS EN 1538.

4) Aggregates – Grading Requirements shall conform to the following table 3.1

**Table 3.1 – Sieve Analysis**

| Sieve Size | Percentage Passing by Weight |
|---|---|
| No. 8 | 100 |
| No. 16 | 95-100 |
| No. 30 | 60-85 |
| No. 50 | 20-50 |
| No. 10 | 10-30 |
| No. 200 | 0-5 |

(1) Fluidifiers: Fluidifiers shall hold the solid constituents of the grout in colloidal suspension, be compatible with the cement and water used in the grouting work, and comply with the requirements of ASTM C937.

(2) Admixtures: Other admixtures may be used subject to no objectionof the Independent Engineer to improve the pumpability, to control set time, to hold sand in suspension, and to prevent segregation and bleeding. Admixtures shall conform to ASTM C494 and shall be compatible with all grout materials, including other admixtures.

(3) Pulverised fly ash shall not be used as a constituent of grouts which contain sulphate resisting cement.

(4) The compressive strength of the grout will be determined by the mix design and the specific end use of the grout.

### 3.15.6 Tail Void Grouting Equipment

(1) General:

(i) Volumetric Measuring Device: Accurate to 5 litres.

(ii) Provide scale device to measure continuously the weight of the grout reservoir.

(iii) Pressure Gauges: Accurate to plus or minus 0.007 MPa over allowable grouting pressure range.

(iv) Grouting system shall be interlinked to the TBM advance.

(v) Provide pressure and volume measurements for each injection line and weight measurements, all continuously fed to the TBM display and TBM Data Monitoring System.

Pumps:

(i) Utilize double piston pumps or hose pumps.

(ii) Each piston of a double piston pump or each hose pump shall feed no more than one injection line to guarantee continuous grout injection.

(iii) Equip with a water connection to facilitate flushing the system.

(iv) Provide an emergency cut-out in case of excessive pressure.

(v) Maintain an adequate supply of spare parts and equipment to assure uninterrupted grouting operations.

(vi) Provide a backup set of grout lines in the shield for use in case primary lines become plugged and cannot be cleaned.

### 3.15.7 Execution

(1) Tail void grout (annulus grouting) shall be volume stable free of excess bleed once in place, with an ultimate strength of 1 MPa.

(2) Perform at a minimum an unconfined compressive strength testing every 50 cubic metres or once per shift, whichever comes first. Perform specific gravity, gel time, bleeding, and flow value testing twice per shift to verify the correct grout mix.

(3) Preparation:

(i) Provide calculations to determine required grouting pressure range along the tunnel alignment to the Independent Engineer for information.

(ii) Maximum grouting pressure shall be adapted to the capacity of the segment lining and the capacity of the sealing systems.

(4) Injection:

(iii) Concessionaire shall provide continuous annulus grouting with appropriate materials during tunnel advance to provide external support to the tunnel lining in the annular void, and limit ovalisation or flotation.

(iv) Tail void grout shall be pumpable through the TBM tail void grout system (i.e., not through grout holes in the segments) with a setting time that permits stoppage of the TBM without risk of plugging the grout pipes or other components.

(v) Remedial cavity grouting of voids that remain after grouting by the TBM tail grouting system may be undertaken by secondary grouting through the grout holes cast in the tunnel lining.

(vi) Ensure minimum effective grouting pressure at outlets which equals the required support pressure taking into account friction losses and other practical requirements to ensure complete filling of the void.

### 3.15.8 Tail Void Grouting Field Quality Control.

(1) As soon as the warning and critical level as specified in Table 3.2 below is reached, the following prescribed work routine applies:

(i) As soon as the warning level is reached, take the following actions:

- Notify the Independent Engineer immediately.
- Adjust work routine to ensure adequate grout quantities are injected into the tail void by modifying grout mix, injection pressures, quantities of admixtures, or other factors.
- Report effects of work routine modifications to the Independent Engineer.

(2) As soon as the critical level is reached, take the following actions:

- Notify the Independent Engineer immediately.
- Stop TBM advance provided that this can be done under safe and secure conditions.

- Report effects of work routine modifications to the Independent Engineer.
- Restart tunnelling procedure upon agreement of the Independent Engineer.

**Table 3.2 – Tail Void Grouting**

| Warning Level | Critical Level |
|---|---|
| Grout volume ≤ 90% of total theoretical volume per ring.<br>*or*<br>Grout volume ≥150% of total theoretical volume per ring.<br>*or*<br>Grout volume ≥150% of total theoretical proportional volume at 3 or more rings. | Grout volume ≤ 90% of total theoretical volume for 3rd consecutive ring. |

(3) Gauges and Meters:

i. Test field gauges and meters in the presence of the Independent Engineer no less often than weekly using master gauges and meters.

ii. Verify accuracy of master gauges and meters through the use of a test laboratory no less frequently than every 2 months.

(4) Adequacy of Grouting:

(i) Conduct tests at grout ports to verify the adequacy of the grouting operations at locations:

- Showing inadequate or excessive grout takes; or
- Selected by the Independent Engineer where leakage is occurring.

(ii) Perform remedial grouting of the test holes in accordance with these specifications.

### 3.15.9 Grout Plugs

Upon completion of grouting, all grout plugs shall be greased and shall be fully tightened into the segment. Hydrophilic 'O' rings shall be provided at all grout plugs.

### 3.15.10 Grout Valves

Al tunnel segments shall incorporate one-way valves to prevent ground, water and grout loss during grouting operation.

### 3.15.11 Monitoring Secondary Grouting Pressures

The Concessionaire shall monitor secondary grouting pressures and quantities to ensure that grouting does not damage the Works or third-party utilities or structures.

### 3.15.12 Caulking

1) Caulking, wherever specified/required, shall be carried out after completion of primary and secondary grouting. Caulking grooves shall be formed in segments in accordance with the design and the specifications to ensure that caulking to circle joints and radical joints may be made effectively and continuous, the depth of caulked material in the joints being not less than 25 mm.

2) Prior to caulking all joints shall be inspected and thoroughly cleaned out as necessary. Any packing shall be cut out by an appropriate method.

3) Immediately prior to caulking, the joints shall be blown out with a compressed air jet to remove any loose debris.

4) Caulking materials shall be forced into the joints so that the full depth is filled. No visible leaks shall remain on completion of caulking.

## 3.16 Ventilation

For ventilation specifications during construction activities refer clause 4.12.2.4 of Schedule D.

## SECTION – 4

## NATM TUNNEL CONSTRUCTION

### 4.1 Design Considerations of NATM tunnels

1) The design and construction of NATM Tunnels shall comply with all the provisions/stipulations of the Contract and include the following,

2) The Concessionaire shall provide a full time Tunnelling Independent Engineer at the work site during excavation and support of NATM tunnel construction, including during excavation and support of tunnel/shaft junctions and tunnel/tunnel junctions. In addition, the Concessionaire shall provide Tunnelling Independent Engineers to cover every shift if there are multiple work shifts. A single Tunnelling Independent Engineer is permitted to cover multiple active excavations during a given shift. Should the Independent Engineer determine that a Tunnelling Independent Engineer for a given shift is not providing adequate supervision of active excavations; the Independent Engineer may order additional Tunnelling Independent Engineers. No additional cost will be paid for multiple Tunnelling Independent Engineers either on a shift or multiple-shift basis.

3) The Tunnelling Independent Engineers shall meet the following minimum requirements:

*(i)* Civil Independent Engineer with a minimum of 20 years of professional experience out of which a minimum 15 years of experience in design and construction of sequential excavation methods for tunnel construction.

*(ii)* Capable of performing the duties in sub-clause 1.3(d) and able to converse with and convey observations and conclusions to the Concessionaire and Independent Engineer

*(iii)* Proficient in written and spoken English

*(iv)* The Tunnelling Independent Engineer shall perform the following duties:

*(v)* Check that the ground support category and round length are appropriate for each advancing round based upon ground condition observations and instrumentation data. Report findings and report on the performance of the initial ground support system to the Concessionaire and the Independent Engineer.

*(vi)* Record exposed geology and the results of probing during excavation. Create a form or template, subject to the Independent Engineer's non-objection, for recording data consistently.

*(vii)* Hold meetings with and advise the Concessionaire's tunnel supervisory personnel on ground support category, ground conditions, and the performance of the initial ground support system. Keep written records of meetings.

*(viii)* Submit weekly reports to the QCE for information on ground conditions encountered, type of support installed, and performance of the various support categories.

*(ix)* Interpret monitoring data with respect to the efficiency of the chosen tunnel support type and the integrity of the initial support during construction.

*(x)* Participate in meetings with the Independent Engineer and the Concessionaire.

*(xi)* The Concessionaire shall submit the qualifications of each Tunnelling Independent Engineer to the Independent Engineer for Notice to Proceed prior to NATM tunnel excavation.

### 4.2 Design Submissions and Method Statement

1) The Concessionaire design shall take adequate measures to minimize the amount of deformations inside the tunnels, thus minimizing the ground relaxation, so as to minimise the ground surface settlements/distortions with a view to comply with all the requirements/provisions of the Contract in respect of EBS protection.

2) The Design Report shall explain the design philosophy, design assumptions, and design parameters for all Civil and Structural works to be undertaken. In addition, the following items shall be contained in the Design Report:

*(i)* Expected performance of the proposed support system for NATM tunnel.

*(ii)* Support system requirements for various geological conditions likely to be encountered.

*(iii)* Sequence of initial support and final support for the tunnel

3) The Concessionaire shall also prepare a Method Statement which presents full details of the design, the materials, equipment, plant and operations involved in the construction of NATM tunnel. The Method Statement shall be consistent with the construction methodology presented in the Design Report. This Method Statement shall be

submitted to the Independent Engineer for Notice in support of the Design Report.

## 4.3 NOTICE TO DESIGN SUBMISSION

1) Preliminary Design and Definitive Design will be reviewed and coded by Independent Engineer in accordance with Clause C9stated hereafter. A Comment Resolution Sheet (CRS) will be attached, listing the Independent Engineer's comments. Return of hard copy drawings with the CRS at this stage is not mandatory.

2) Construction Reference Drawings shall be reviewed by Independent Engineer in accordance with Clause C9 stated hereafter. Comment Resolution Sheet will be attached. Drawings reviewed with review Code 'A' or 'B' will be stamped with Notice to proceed and signed by the Independent Engineer. Two sets of hard copy drawings will be returned to the Concessionaire.

3) Construction Reference Drawings accorded with Code 'B' should be resubmitted after incorporating the Independent Engineer's comments within 30 days of receipt of the concerned set of time. The Concessionaire shall unless otherwise provided, be liable for and shall indemnify the Authority against all costs, charges, expenses and the like resulting from the failure of Concessionaire to co-ordinate the works as specified.

## 4.4 Types and General Construction Methods

1) The configurations and profiles of NATM tunnels as shown in the tender drawings are for information only and indicative, the same shall be detailed/finalized by the Concessionaire duly complying all the Contract provisions/requirements. The proposed profiles of the NATM tunnels, including that of tunnel invert shall be suitable for the applicable ground conditions.

2) The top of pavement alignment is shown on the Authority's tender drawings. Unless specified otherwise, the NATM tunnels shall generally be in horseshoe profile with appropriate invert profile suitable for the applicable ground conditions. Changes in profile require Non-objection by the Independent Engineer.

3) NATM tunnels are in general expected to be in weak, hard rock and mixed ground conditions.

4) Initial ground support (primary support) for the NATM tunnels is expected to comprise, rock dowels, rock anchors, lattice girders, steel ribs, spiles, pipe-roof, plain or reinforced shotcrete and a combination of the aforesaid supports.

5) The final ground support (permanent support) for the NATM tunnels is expected to be plain or reinforced cast in-situ concrete lining. The design of final ground support shall ignore the presence/contribution of initial ground support.

6) The Concessionaire shall be responsible for the safety and security of excavations at all times during the execution of the Contract.

7) The Concessionaire shall present to the Independent Engineer for Notice, details of his proposed methods for excavation, spoil removal, ground treatment, installation of initial support and final support construction prior to commencing any construction works.

8) Excavation shall be carried out in a uniform and controlled manner, over-cutting or over- excavation shall be kept to a minimum. No excavation shall take place until the Independent Engineer's Notice has been obtained.

9) The Concessionaire shall adopt such appropriate methods and take such steps as are necessary to control water in-flows and movement into the tunnel being excavated and to maintain the stability of the excavation.

10) Where the Concessionaire's site and EBS investigations indicate that there are already limits in imposition for movements, distortions and/or protection in respect of existing adjacent EBS, the Concessionaire shall provide calculations to demonstrate that the method of excavation will result in compliance of all those limits/requirements. The Concessionaire shall also comply with the requirements of the Relevant Authorities with regard to movements or distortions of these EBS.

11) Where such limits/requirements are not specified by the Relevant Agencies/Authorities, the Concessionaire shall assess each EBS that may be affected by the Works and submit his proposed limits of movements and distortions that are needed to be imposed for those EBS, to ensure compliance to the provisions of the Contract and seek a Notice to Proceed from the Independent Engineer.

12) The Concessionaire shall submit to the Independent Engineer details of his proposed instrumentation and monitoring arrangements for ground and EBS movement and distortion and changes to the groundwater table(s) and the trigger (Alert, Action & Alarm) levels for each and every identified EBS and/or monitoring instrument in accordance with the Contract.

## 4.5 Tunnel Design Requirements

1) The design life of final support shall be 100 years and that of non-structural components as 50 years.

2) The design Fire Resistance Period for the segmental lining of the tunnel shall be 4 hours without spalling of concrete.

3) Minimum grades of Shotcrete and concrete shall be M30 and M35 respectively.

4) The excavation sequences for heading, benching and invert shall be designed in such a manner that the deformations inside the tunnel shall be limited to the design deformations as considered in fixing the excavation profile. The design calculations for the support system shall be carried out with standard software available in the market, e.g. UDEC, 3DEC, FLAC, PLAXIS, etc. However, the Software proposed to be used by the Concessionaire shall have been validated on similar applications and if found necessary, the Concessionaire shall submit the required documents/details in support of such validation. The design submitted for the same shall also indicate the adjustment for support system requirement with respect to the instrumented data gathered during execution.

5) During the tunnel excavation, the water-inflow shall be controlled to meet all the obligations and responsibilities of the Concessionaire as stated in the Contract. For this purpose the required ground treatment/ dewatering, as may be necessary, shall be undertaken by the Concessionaire.

## 4.6 Design Loads

1) The design method shall consider in-situ ground stresses and shall provide evidence and/or measurements in support of the parameters adopted in the design as part of the calculations. The ground load on the tunnel shall be based on the actual height of overburden above the tunnel lining and the coefficient of earth pressure at rest of the soil strata surrounding the tunnel and the rock loading as worked out from the rock- mechanics Independent Engineering principles. The effect of over-consolidation of ground shall not be considered in the design of final ground support of tunnel.

2) The design shall take into account all additional loads, stresses and strains imposed by or on adjacent EBS and assumed distortions and loads by or on the NATM tunnels.

3) Where NATM tunnels are adjacent to or beneath EBS, the design shall demonstrate that these EBS shall not be subjected to unacceptable movement, distortion or loss of support which endangers the stability of the EBS and that any resulting movements and distortions will be within prescribed limits determined by the authority for that EBS, the Independent Engineer, or by the Concessionaire as agreed with the Independent Engineer.

4) Linings shall be designed to withstand all environmental loadings, distortions and other effects without detriment. In general, NATM tunnel support shall be designed to fulfil the following requirements and to resist the following loads.

5) Superimposed surface loads from traffic, existing structures over and adjacent to the NATM tunnel, and any specified future loads.

*(i)* Appropriate ground loads (including soil load, rock load and rock wedge load), water pressure, and seismic loads.

*(ii)* Traffic loads

*(iii)* Superimposed dead and live loads from utilities, services, systems' provisions, pathways & walkways and structural elements within the tunnel etc.

*(iv)* Structural requirements for resisting buckling.

*(v)* Long- and short-term ground yield or squeeze.

*(vi)* Unequal grouting pressures.

*(vii)* Adjacent bored/NATM tunnelling or excavation.

*(viii)* Openings in, or extensions to, the lining.

*(ix)* Long- or short-term loads induced by construction.

*(x)* Temperature and shrinkage.

*(xi)* Accidental loading such as fire and vehicle impact.

*(xii)* Any other loads as considered appropriate and necessary.

6) The design shall also consider the relative rates of loading / unloading in both the lateral and vertical directions, and the resultant induced tunnel deformations whether temporary or permanent.

7) The design of the NATM tunnel linings shall take into account the proximity of other tunnels one to another, the sequence and timing of construction and the proximity of adjacent EBS.

8) All components of underground structures shall be proportioned to withstand the following applied loads and forces.

*(i)* Dead load comprises the self-weight of the basic structure and secondary elements supported and the ground load. The depth of cover shall be the actual depth or a minimum of 3 metres. The depth of cover shall be measured from the ground surface to the tunnel crown.

*(ii)* Traffic surcharge shall be equivalent to Class AA loading of IRC-6. Latest revision.

*(iii)* Loads from existing or known future adjacent structures above or within the area of influence, which will remain in place above the NATM tunnels, or any specified future loading. The applicable foundation load and its influence shall be computed based on the type and use, and the foundation type which supports that structure.

*(iv)* Additional support, ground treatment or additional lining thickening shall be provided unless it can be shown that adequate provision already exists.

*(v)* Where provision for a specific future structure is not made a minimum uniformly distributed surcharge of 50kPa at the design finished ground level shall be assumed.

*(vi)* Hydrostatic pressure, ignoring pore pressure relief arising from any seepage into the tunnel. For derivation of hydrostatic pressure, the maximum groundwater level shall be taken as the 1 in 50 year return period water level or actual water level at the time of construction whichever is the higher, plus a 1.0m allowance for sea level rise. The minimum groundwater level shall be taken as the lowest recorded value minus 3m or the level to which the groundwater table may be drawn down during construction, whichever is lower.

*(vii)* Where necessary, loads and load changes due to known construction activity in the vicinity of the NATM tunnel, such as the excavation and the formation of underpasses, basements, pile groups, bridges, diaphragm walls and cable ground anchors and the like.

9) For members exposed to earth/ground and ground water (tunnel support), the maximum design crack width shall not exceed 0.2 mm irrespective of whether any additional protections, such as waterproofing membrane, are provided to the members at the exposed face (ground face) of the structure. However for the non-ground face (intrados of support) of the members, the maximum deign crack width shall not exceed 0.3mm.

10) The permanent NATM tunnel support shall be designed and checked for all possible combinations of applied loads and forces.

### 4.7 NATM Tunnel Support - Initial Support

1) Where tunnelling is carried out by NATM principle, temporary support is expected to be pipe piles, spiles, structural steel sets, lattice arch girders, base plates, ties and connections and lagging sprayed concrete (shotcrete) or cast-in-situ concrete. All of them shall comply with the relevant standards and may be used together with appropriate ground pre-treatment as deemed necessary for the ground conditions likely to be encountered.

2) Steel sets and lattice arch girders shall be rolled to suit the dimensional requirements of the designed opening. The Concessionaire shall provide dimensional details of the steel sets or lattice arches girders and lagging which include all calculations regarding imposed loads before and after any ground pre-treatment.

3) Spiles shall be steel rods or tubes of outside diameter not less than 32 millimetres.

4) Pipe piles shall be steel tubes of outside diameter not less than 40 millimetres.

5) Rock dowels shall be non-tensioned steel bars threaded at one end and provided with a face plate, shim plates and a conical seated washer and nut, or split or deformed steel tubes, or glass fibre reinforced resin rods.

6) Rock bolts shall be tensioned bar manufactured out as one of the following types solid steel bar, slit or deformed steel tube, glass fibre reinforced resin rods.

7) Alternative materials shall be subject to the Notice to Proceed from the Independent Engineer.

### 4.8 NATM Tunnel Support – Final Support

1) The tunnel final support constructed by NATM method shall be cast-in-place concrete (plain or reinforced)

that are held securely in place and will remain so for all known possible future conditions.

2) The Concessionaire shall take into account all of the following when considering the design of the final support.

*(i)* The internal dimensions required to accommodate the Kinematic Envelope,

*(ii)* Structure Gauge, and pavement arrangement

*(iii)* Due allowance for relative movement between tunnels and cut-and-cover structures as described in the Contract.

*(iv)* The stiffness of the permanent lining shall be sufficient to limit the allowable deflection on radius under the expected loadings to a maximum of 10 millimetres with a maximum longitudinal distortion of 10 millimetres in 10 meters (1 in 1000) and a transverse distortion (ovalisation) of 4 millimetres in 6.0 metres (1 in 1500).

*(v)* Short-term (during construction), intermediate (immediately after construction) and long-term (full design life) loading conditions.

*(vi)* Stresses induced by grouting.

*(vii)* Ground pre-treatment, where applicable.

*(viii)* The reinforcement for final tunnel support shall be detailed such that there is no electrical continuity across the construction joints. To prevent the stray effects and to inhibit the corrosion, suitable property enhancers shall be added in to concrete. Such concrete shall be tested in accordance with ASTM C 1202 and DIN 1048. RCPT value shall not exceed 1000 coulombs (at the concrete age of 28 days) and Water permeability shall not be more than 10.

*(ix)* millimeters (at the concrete age of 28 days). Reinforcement of in-situ concrete lining shall be bonded to mitigate stray currents. The bonding shall be part of the corrosion control system designed and installed by the Concessionaire to the Notice to Proceed by the Independent Engineer. The corrosion control system shall be tested and proven to the satisfaction of the Independent Engineer that the corrosion control system functions as designed in all locations.

*(x)* For Bonding and earthing of Tunnel Support (Stray Current Protection), the Concessionaire shall provide stray current protection for the tunnel support in accordance with the Contract.

*(xi)* The formation of blind holes and all other fixings for brackets and equipment shall be detailed such that they have no adverse effect on the integrity, water- tightness and design life of the linings.

**4.9 Construction Considerations of NATM tunnels** – Excavation

**4.9.1 General**

(1) The Concessionaire shall carry out NATM works in accordance with the Concession Provisions and conforming to the dimensions shown on the detailed design drawings that have received a Notice to Proceed from the Independent Engineer.

(2) Prior to the commencement of any tunnel excavation Works by conventional mechanical means, a Method Statement shall be submitted to the Independent Engineer for approval. The Method Statement shall confirm as a minimum;

(3) The technique, procedures, equipment, materials and personnel for the tunnel excavation Works and all related activities.

(4) Sequence of excavation phases, in relation to the shotcrete application and the installation of all other necessary primary support measures.

(5) Construction supervision plan.

(6) A risk analysis, related to the individual tunnelling works, which shall identify hazards and estimate the level of risk arising from the hazard, and the proposed control measures.

(7) The contingency plan, monitoring, evaluation and related measures and procedures for emergencies.

(8) Criteria for the selection of the tunnel primary support section, in accordance with the Concessionaire ’s design.

(9) Description of the investigation probe holes and the proposed method of primary support.

(10) The safety and security of all works under the Concession shall, at all times during the construction, be the

responsibility of the Concessionaire. The Concessionaire shall implement such measures, including supporting, dewatering and ground treatment/improvement etc., as may be necessary to fulfil his obligations under the Concession.

(11) The Concessionaire shall construct the Works under the Concession in such a way that the ground surface settlement and distortion effects are kept as small as possible and, in any case, not exceeding the limits that would infringe any of the Concession provisions in this respect. Suitable measures shall be taken to ensure that all the Concession provisions are complied with. Such measures shall include, but not be limited to:

a) special tunnelling methods to reduce ground loss;

b) protection measures such as:

- Underpinning
- ground improvement
- ground treatment
- compensation grouting
- structural jacking and supporting
- structural strengthening
- curtain walling
- other suitable supporting methods

c) Excavation with Care:

d) All necessary precautions shall be taken in order to prevent softening or deterioration of excavation surfaces such as installation of initial support as quickly as possible etc.

e) Where necessary to ensure the safety and security of the Works, excavation for underground Works shall be continuous by day and night. The Concessionaire 's procedures may allow intermissions at weekends and general holidays, provided the Works are safe at all times and are inspected by the Concessionaire at appropriate intervals. Appropriate temporary support shall be provided to excavated faces during period of short-term stoppage. In the event of long-term stoppage temporary support equivalent to the detailed design shall be installed.

f) In case of NATM tunnelling the Concessionaire shall make adequate arrangements to support the face in an emergency. The support system shall be maintained in good order at all times and it shall be stored as close to the face as practicable. A detailed drawing of the support system shall be available close to the tunnel face for reference.

g) Temporary support may be required to the face during manual excavation. The type of support to be provided must suit the ground conditions and be non- objected by the Independent Engineer. The method of support should be included in the non- objected NATM method statement.

h) Where the excavation is to be discontinued for any period of time, the excavated tunnel shall be adequately supported, and the face shall also be supported in such a manner that ground movement is prevented.

### 4.9.2 Excavation Method and Equipment

(1) Rock excavation shall be performed by using road header, excavator or breaker, expansive chemical agents etc. depending upon the ground conditions and site constraints. The method of excavation shall be Non-objected by the Independent Engineer.

(2) Road header shall have transverse type of cutter head and shall be capable of working in the type of rocks likely to be encountered in the tunnel excavation.

### 4.9.3 Disposal of Excavated Material

Surplus excavated material shall be treated as Client's property. The Concessionaire shall only be able to dispose of surplus spoil in the manner non-objected by the Independent Engineer. Disposal of all spoil shall be in the Concession sum and any associated costs shall be at no additional cost to the Concession. Alternatively, at the no objection of the Independent Engineer, surplus spoil may be used.

The muck/spoil that is acceptable to be used elsewhere in the works or can be used at a later stage in the Works, shall be temporarily stockpiled in a dumpsite proposed by the Concessionaire and non- objected by the Independent Engineer and the concerned regulating authorities.

The muck/spoil, which is not acceptable or cannot be accommodated for use in the Works or cannot be made use of by the Concessionaire for his own purpose, shall be disposed of in spoil dumps or elsewhere as approved by the Independent Engineer/concerned parties and regulating authorities.

### 4.9.4 Excavation for Concessionaire 's Convenience

Excavations for the Concessionaire 's own use and convenience shall conform in every respect with the Authority's Requirements. For this purpose, the Concessionaire shall submit detailed proposals to the Independent Engineer for obtaining his Notice to Proceed. The proposals shall include the Concessionaire 's method of backfilling and reinstatement.

### 4.9.5 Definition of Excavation Profile

(1) The finished tunnel profiles as shown on the Authority's indicative Tender Drawings are only for information and the concept adopted is shown in the following Figure 4.1 below.

(2) Depending on the quality of the rock/ground, the proposed theoretical excavation line shall consider the applicable deformation tolerances so that the as-built tunnel doesn't infringe the required finished tunnel profile.

(3) The proposed theoretical excavation line shall also consider the proposed construction tolerances (as-built tolerances) so that the as-built tunnel doesn't infringe the required finished tunnel profile.

(4) Deformation tolerances (including the tunnel convergence and ground relaxation) are to be proposed by the Concessionaire, based on detailed analysis so as to contain the ground surface settlements and distortions to protect the EBS against damage and to comply all the Concession provisions in this respect, for obtaining a Notice to Proceed from the Independent Engineer.

(5) The actual deformations (including tunnel convergence and ground relaxation) during tunnel construction shall be contained within the proposed deformation tolerances and the adjustments made to the tunnel support and excavation sequence etc. The tunnel excavation shall ensure that the actual deformations do not exceed the tolerances that have been agreed by the Independent Engineer.

(6) The Concessionaire shall contain the actual construction tolerances during construction within his proposed construction tolerances.

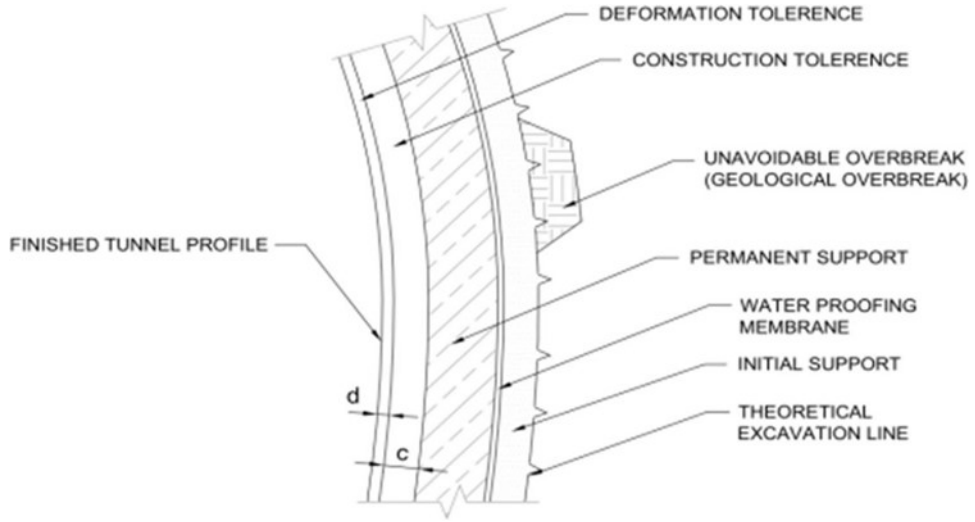



**Figure 4.1 - Definition of Deformation and Construction Tolerances**

### 4.9.6 Method of Profile Control

### A. General

(1) It is the Concessionaire's responsibility to ensure that the finished tunnel profile including the installation of structural fire protection complies with the Project schedule of dimensions and all other requirements of the project including the kinematic envelope for the safe passage of vehicles, installed M&E and Fire safety systems. The final tunnel finished profile shall be Non-objected by the Independent Engineer. The Concessionaire shall propose a methodology for the systematic checking of the tunnel geometry and finished profile. This methodology will have a Notice to Proceed from the Independent Engineer.

(2) The Concessionaire shall use advance surveying techniques and data processing to establish the required "finished tunnel profile" and define a method of marking out areas of deviation from the required "finished tunnel

profile" with a Notice to Proceed from the Independent Engineer.

**B. Execution**

(1) The Concessionaire shall determine the excavation sequences and the ground support categories, considering the ground stand-up time and groundwater infiltration as defined in the non-objected Geotechnical Interpretative Report completed by the Concessionaire, which shall be in conformity with relevant Indian & International Codes. This work includes the temporary support to facilitate excavation and support to the full final opening dimensions.

(2) The Concessionaire shall construct sequentially excavated tunnels and underground openings in accordance with the concepts of the New Austrian Tunnelling Method (NATM) of convergence/confinement. Initial or temporary ground support shall be placed to attain stress equilibrium ceasing ground movement following excavation. Use of NATM may require oversizing the opening to allow access for the Concessionaire 's equipment and personnel.

(3) The Concessionaire shall carry out the Tunnel Risk Assessment to identify hazards, estimate the level of risk arising from the hazard, confirm the proposed control measures, include a contingency plan, monitoring details and procedures for emergencies. The criteria for the selection of the tunnel primary support section shall be in accordance with the Concessionaire 's design.

(4) Prior to the commencement and throughout tunnel excavation Works, as well as after their completion, the Concessionaire shall ensure all monitoring instruments that have been installed are fully functional, regularly calibrated and monitored. The Independent Engineer may instruct the stoppage of the Works when the instruments are not completely installed, or the Concession requirements are not fulfilled.

(5) The Concessionaire shall provide safe workspaces, access, and temporary platforms at all times.

(6) Necessary equipment in working order shall be present at site at all times for installation of support, face support, contingency procedures, and other approved measures.

(7) NATM excavation may only commence following completion of ground improvement to form stable ground. Ground improvement methods shall be determined by the Concessionaire and shall be based on the ground conditions as detailed in the non-objected Geotechnical Interpretative Report completed by the Concessionaire.

(8) The Concessionaire shall perform sequential construction in a manner that minimizes ground movement in front of and surrounding the excavation and settlements of structures and utilities above and in the vicinity of the excavation.

(9) The Concessionaire shall excavate to lines, grades, and dimensions and tolerances, as shown in the Non-objected NATM design which includes tolerances and deformations to accommodate initial support and final lining system.

(10) The Concessionaire shall assess all ground and groundwater conditions, ground movement, and lining deflection at all times during the sequential excavation period and react proactively to all indicators of unsafe conditions.

(11) The Concessionaire shall open up a new excavation round only following the complete installation of necessary initial support elements of the previous round and for a length not exceeding the maximum length of unsupported excavation indicated for the respective ground support category.

(12) Contingency procedures shall be implemented as warranted by the actual ground conditions encountered and in addition to regular measures established by submittals for sequential excavation and support operations.

(13) In case of emergency or work stoppage likely to endanger excavation or adjacent/overlying structures, the Concessionaire shall continuously maintain full work force 24 hours per day including weekends and holidays until emergency or hazardous conditions no longer jeopardize stability and safety of the structures.

(14) The Concessionaire shall document stability of the final excavated opening (full cross- section) by examining data from the installed Geotechnical Instrumentation.

(15) The Concessionaire shall prove the absence of any continuing and significant deflection or increase of stress before installing the final structural lining.

(16) Initial and temporary ground support shall be designed by the Concessionaire and may consist of reinforced shotcrete with ground support elements, steel pipe, reinforced concrete pipe, or concrete segments.

(17) The Concessionaire shall install temporary ground support elements to support ground continuously in a manner that prevents loss of ground and maintains stability of the excavated perimeter and headings and in accordance with approved methods statements.

(18) The Concessionaire shall install ground support in accordance with methods statements non- objected by the Independent Engineer as soon as practical after excavation and spoil removal at the face.

(19) Changes or modification to the excavation sequence and/or ground support shall not be permitted without prior no objection of the Independent Engineer or in the case of an Emergency such as an immediate safety issue.

(20) The Concessionaire shall carry out monitoring and instrumentation to observe the ground behaviour, to verify the performance of the ground support, to assist in the proper timing of the closure of the ground support ring, and to further aid in the selection of ground support.

(21) The Concessionaire shall install ground support to achieve safety of the work and personnel and to permit the openings to remain stable until the final structural lining is installed. Working beneath unsupported ground shall not be permitted for obvious safety reasons.

(22) The Concessionaire shall drill probe holes ahead of the advancing tunnel face as required. The Concessionaire shall perform probe hole drilling using a standard hydraulic percussion drill. Measure the rate of penetration to determine changes in the resistance of the ground to penetration. The Concessionaire shall stop drilling at regular intervals to determine the rate of water inflow.

(23) Ground shall be fully supported during the last work shift prior to weekends, holidays not worked, and shutdowns. During shutdowns, the tunnel face shall be positively secured. The securing of the tunnel face shall include a means to prevent the ingress of water and face instability.

(24) The Concessionaire shall maintain suitable experienced personnel on duty to monitor conditions that might threaten the stability of the excavation whenever the tunnel excavation is suspended or shutdown.

(25) A clear means of egress in an emergency shall be provided and always maintained. Minimum dimensions shall conform to appropriate international standards.

## 4.10 Construction Tolerance

### 4.10.1 Tolerances for Lining

The actual thickness of the final support shall not be allowed to be less than the designed thickness of the final support unless non-objected by the Independent Engineer. To achieve this requirement, no support elements such as primary shotcrete (initial support), rock bolts and steel ribs etc. shall penetrate into the theoretical outer boundary of the final support (inner lining), as shown on the construction drawings.

### 4.10.2 Over- Break

(1) Over break is the space created when the ground breaks beyond the theoretical excavation line. Unavoidable over-break may be caused by unfavourable geological conditions or poor workmanship. In the event of excessive over-break, support shall be installed immediately as required to stabilize the ground. The Independent Engineer shall be informed immediately and the remedial works shall be proposed by the Concessionaire for obtaining a Notice to Proceed from the Independent Engineer.

(2) The remedial works shall be executed before further advance of the face unless agreed by the Independent Engineer.

(3) Where over break occurs more than 150 mm beyond the theoretical excavation line, the Independent Engineer will inspect the area and decide if shotcrete or concrete shall be provided as backfill. In areas where there is to be a concrete lining or concrete structure adjoining the rock, the over break backfill shall be of the same quality as that required for the lining or structure. The remedial works for the over-break (whether avoidable or unavoidable) shall be carried out by the Concessionaire at no extra cost to the Authority.

### 4.10.3 Concessionaire 's Submission

The following shall be submitted to the Independent Engineer for his Non-objection

(1) The Concessionaire shall submit a method statement to the Independent Engineer for no objection for all NATM tunnelling works that includes detailed descriptions, shop drawings, design calculations, manufacturer's literature and other pertinent information covering proposed equipment and materials to be used including but not limited to the following:

i. Size, sequence, and timing of excavation of individual headings, including planned round lengths, excavation methods to be employed, materials to be utilize, equipment, and implementation procedures.

ii. Sequencing and methods required to create the NATM opening in the TBM tunnel or cut & cover.

iii. Design and implementation of a temporary bracing system inside the TBM tunnel or shaft when the opening is created.

iv. Design and construction of the concrete collar inside the tunnel or shaft providing stability of the tunnel or shaft lining after the temporary bracing is removed.

v. Types of initial ground support elements to be installed in each individual heading.

vi. Identify the length of unsupported sections and time for application of support elements.

vii. Details on excavation and removal of all temporary initial support as adjacent individual headings are advanced to progressively open up the full excavation cross-section

viii. Survey methods to include type and location of horizontal and vertical control, procedures, frequency, and equipment

(2) The Concessionaire shall submit the following Contingency Procedures to the Independent Engineer for non-objection:

(i) At least 30 days before start of NATM excavation, the Concessionaire shall submit contingency procedures that address particular ground and site conditions as described in the Concessionaire s non-objected Geotechnical Interpretative Report.

(ii) As a minimum, the contingency procedures shall include the following information:

a) Names and qualification of personnel responsible for implementing contingency procedures

b) Descriptions of conditions considered to require contingency measures

c) Materials to be used for contingency measures, including ground support and formation grouting

d) Methods and equipment to be used to implement contingency measures, including both ground support and formation grouting.

e) Specific plans outlining measures to be undertaken in the event that the following conditions occur;

(1) Excessive over break

(2) Face or rock instability

(3) Deformation beyond expected values

(4) Excessive groundwater infiltration rate and/or quantity

(5) Methods to verify successful implementation of contingency measures

(6) Arrangements for monitoring conditions during longer stoppages such as weekends and holidays as well as directed stoppages

(7) Procedures detailing measures to be applied for the resumption of excavation operations after stoppages

(3) The Concessionaire shall submit a weekly report to the Independent Engineer for information on all geologic features encountered during NATM excavation operations in the relevant period. The geologic report shall include information on rock type, groundwater conditions, average excavation progress, and other relevant observations. The geologic report shall also include a summary of information on the instrument readings in relation to the excavation performance.

(4) The Concessionaire shall submit, but not be limited to providing the following information to the Independent Engineer for obtaining Notice to Proceed, at least 60 days before the commencement of any NATM tunnel work.

i) The name and qualification of the independent geotechnical Independent Engineer (who shall be required to be deployed for the Works by the Concessionaire for advising the support requirements) proposed by the Concessionaire for Notice to Proceed from Independent Engineer.

ii) Relevant training certificates and work experience of the shotcrete nozzle men and other personnel proposed to be deployed by the Concessionaire.

## 4.11 NATM TUNNEL SUPPORT

### 4.11.1 General

(1) The type and amount of tunnel support to be installed immediately after excavation is directly related to the

rock classification as established by the Concessionaire in his design. The standard initial support associated with the established rock classification system shall be proposed by the Concessionaire for obtaining a Notice to Proceed from the Independent Engineer.

However, as a consequence of variations from the anticipated rock conditions the standard support systems as shown on the Construction drawings (prepared by the Concessionaire and non-objected Notice given by the Independent Engineer) for each rock class may require modifications and adjustments during construction for which a further Notice to Proceed for the revised scheme shall be obtained from the Independent Engineer.

(2) The Concessionaire shall ensure that support elements are installed or applied in such a manner, time and sequence as to prevent disintegration and loosening of the rock mass surrounding the excavated tunnel.

### 4.11.2 Initial Tunnel Support

(1) The initial tunnel support will generally consist of the following:

- Steel ribs or lattice arches and wire/reinforcement mesh sprayed with shotcrete to an appropriate thickness
- Shotcrete with wire/reinforcement mesh or fibre and rock-bolts/rock- dowels
- A combination of the above.

(2) Wherever ground conditions require pre-support, the Concessionaire shall provide the same by way of inserting an 'umbrella' type fore poling either by installing a pipe roof that will be closed poled or spiling with grouted pipes or bars depending on the ground stability.

(3) Where the water in-flow into the excavation is expected, ground treatment such as grouting, ground freezing etc. shall be done by the Concessionaire before commencing the excavation. However, the localised dewatering in the tunnel face can be carried out by either drainage pipes inserted into the face or a mild vacuum system duly ensuring that it doesn't lead to unacceptable ground surface settlements/distortions adversely affecting the EBS.

(4) The initial Support will be monitored continually for settlements/deformations throughout the stabilisation process. Other monitoring shall include force in rock bolts and stresses/strains in shotcrete lining.

(5) The initial support system including the design of the supporting pattern with respect to each Rock Class shall be determined and proposed by the Concessionaire for obtaining a Notice to Proceed from the Independent Engineer before commencing the works.

### 4.11.3 Final Tunnel Support:

The final tunnel support shall comprise of Concrete lining (or reinforced concrete lining).

(1) Concrete lining; The Concessionaire shall design concrete linings to meet the requirements of the Concession Specifications pertaining to concrete.

(2) Preparation of surfaces; The surface against which concrete is to be placed shall be cleaned of loose material, dirt, oil and grease. A waterproofing membrane shall be placed between the initial support and the final concrete lining. No concreting of final support shall take place before inspection of the initial support surface and the waterproofing membrane by the Independent Engineer.

(3) Placing of concrete; Concrete shall be placed so that the space between the lining form and the surface against which concrete is to be placed, is filled as completely as possible, to avoid any voids formation especially in the crown area. After the placed concrete attains a 28-day strength, the interface between the concrete lining and the initial support shall be contact grouted without damaging the waterproofing membrane.

### 4.11.4 Sprayed Concrete (shotcrete)

#### 4.11.4.1Submittals

(1) The Concessionaire shall submit the following to the Independent Engineer for no objection prior to proceeding with preconstruction testing:

(i) Product Data: For manufactured materials and products, generally including reinforcement, anchorage studs, forming accessories and sprayed concrete materials.

(ii) Material Test Reports: For sprayed concrete materials.

(iii) Sprayed concrete design strengths according to BS EN 14487-1.

(iv) Mix design for each sprayed concrete type. Indicate wet mix process or dry mix process and type of

reinforcement for each mix design.

(v) Method Statement which includes at a minimum the following:

1. Specifications and descriptions of equipment to be used

2. Application method

3. Batching method

4. Description of the preconstruction testing programme including, at a minimum, a drawing of the proposed test panel, locations and method of anchoring test panels, date and time for test panel concreting, method of spraying each test panel (e.g., vertical, horizontal, using special equipment) and number of test panels to be completed for each method

(vi) Samples of all sprayed concrete ingredients and product supplier data

(vii) Statement of Qualifications and Certification for those performing the Work as per ACI CP-60(02), Craftsman Workbook for ACI Certification of Shotcrete Nozzleman:

1. Nozzlemen

2. Supervisor(s)

3. Name(s) and experience record of the firm(s) performing the work

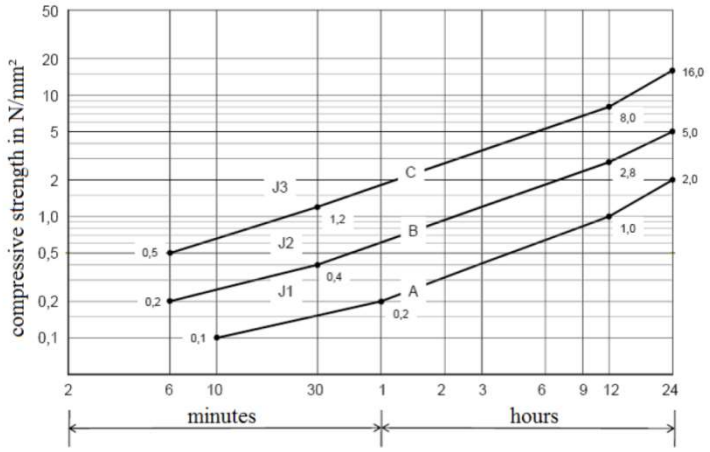
4. References

**4.11.4.2Performance & design of Shotcrete.**

(a) Early Strength: The early strength of shotcrete shall conform to the early strength class J2 according to the below figure. For explanations regarding the use of Early Strength Classes J1, J2 and J3 Austrian Guideline for Shotcrete may be referred to.

(b) The measurement of early strength shall be done by using the penetration needle, Hilti Shot bolt(stud-bolt) system (or equivalent) according to the Austrian Guideline for Shotcrete, August 2006.

(c) Further Strength Development: The 72 hours strength of the shotcrete shall be at least 12.5 N/mm2. The




between A and B class $J_1$
between B and C class $J_2$
above C class $J_3$

strength of the shotcrete after 7 days shall be at least 70% of the specified 28 days strength of the mix.

(d) Final Strength: The 28 days strength of shotcrete shall be as per design mix of the concrete. A maximum factor of 0.85 (the ratio of in-situ strength to the design mix strength) shall be taken into consideration while designing the mix to account for the effects of insitu installation conditions as compared to the conditions obtainable in the Field Suitability tests.

(e) Durability: The chloride content of the in situ sprayed concrete shall not exceed the values that are specified in IS: 456 for concrete. The alkali content of the aggregate shall comply with the requirements of IS:456 to prevent alkali-silica reaction.

**4.11.4.3Quality Assurance**

(1) Nozzle operator shall be certified as per ACI CP-60(02), Craftsman Workbook for ACI Certification of

Shotcrete Nozzleman.

(2) Nozzle operator shall have a minimum of 3 years' experience on projects of similar nature and the work should be performed under the supervision of a foreman/supervisor with a minimum of 3 years' experience on projects of similar nature.

(3) Before conducting field trials, the Concessionaire must submit to the Independent Engineer for non- objection written evidence of the qualifications of the nozzle operator and supervisor.

(4) Each nozzle operator shall demonstrate, using the specified material and proposed equipment, acceptable proficiency in applying sprayed concrete uniformly in both the vertical and overhead orientations.

(5) Proficiency shall be demonstrated through the use of vertical and overhead test panels that reflect the actual jobsite conditions.

### 4.11.4.4Products, Materials & Additive's Placing Equipment

(a) Sprayed concrete placing equipment shall be capable of introducing materials to the delivery hose at a uniform rate with material exiting from the nozzle at a velocity and a consistency that will ensure adhesion to the surface with minimum rebound and maximum density.

(b) For dry mix application, water supply system shall be capable of supplying the necessary amount of water through a manually operated liquid injection system (water ring) so that the nozzle operator can easily control amount of water. If variations in water pressure cause wet/dry fluctuations at the nozzle, sprayed concrete application should be terminated until the situation is resolved.

Admixtures

Admixtures shall have the required consistence for spraying in accordance with BS EN 14487-1 and have previous acceptable performance on similar projects with sprayed concrete. Admixtures shall not contain water-soluble chlorides or materials corrosive to steel nor be subject to other detrimental effects such as cracking, spalling, or debonding.

Silica Fume

Silica fume shall have previous acceptable performance on similar projects with sprayed concrete.

Fibre Reinforcement

(a) Sprayed concrete may be fibre reinforced. Fibre reinforced sprayed concrete shall contain steel fibres in compliance with BS EN 14889-1 or collated fibrillated polypropylene fibres.

(b) Steel fibres shall have bent or deformed ends or be continuously deformed throughout.

(c) Collated fibrillated polypropylene shall be a collated fibrillated polypropylene pre-twisted fibrous bundle. Monofilament polypropylene or polyester in any form will not be acceptable substitutes for collated fibrillated polypropylene fibres.

### 4.11.4.5Execution

(1) General

a) All surfaces to be in contact with sprayed concrete must be free from dust, oil, grease or any other foreign substances that may interfere with the bond of the material.

b) Sprayed concrete shall be placed and protected according to ACI 305 when hot- weather conditions and high temperatures would seriously impair quality and strength of sprayed concrete. The ingredients shall be cooled before mixing to maintain sprayed concrete temperature at time of placement below 38 degrees C.

(2) Preliminary Mixes and Pre-construction Testing.

a) The Concessionaire shall perform accelerator compatibility tests of the proposed sprayed concrete mix designs to determine cement and additives to be used in the subsequent field tests.

b) Following successful preliminary mix tests, the Concessionaire shall conduct field preconstruction tests by constructing sprayed concrete test panels, as indicated as described herein Clause 4.7.4 and at least 30 days prior to the actual application of sprayed concrete for the Works.

c) The preconstruction testing of mixes shall be carried out in accordance with the requirements of BS EN 14487-1, Table 9, Inspection Category 3 for Strengthening of Ground.

d) Testing shall be carried out on a sufficient quantity of sprayed concrete in order to reach a uniform flow. It shall be demonstrated that the requirements can be met before the start of execution.

e) The Concessionaire shall perform field preconstruction tests for each approved mix design to demonstrate the capability of equipment, workmanship, and materials under field conditions. The mixes selected for preconstruction tests shall be confined to those approved by the Independent Engineer following preliminary mix testing. The Concessionaire shall provide the Independent Engineer with the opportunity to witness the production and testing of core samples.

(3) Sprayed Concrete Panel

a) All sprayed concrete test panels shall be constructed at locations non-objected by the Independent Engineer by each qualified nozzleman using equipment, materials, mix design, and procedures submitted and non-objected by the Independent Engineer. Each nozzleman shall construct one test panel for each mix design and one panel for each spraying position. At a minimum, one horizontal overhead and one vertical spraying position shall be completed for each proposed mix. Nozzlemen will not be permitted to apply sprayed concrete in the field for any spraying position that is not tested.

b) The Concessionaire shall produce test panels before sprayed concrete placement according to requirements in ACI 506.2 and ASTM C1140 for each design mix, shooting orientation, and nozzle operator. Produce test panels with minimum dimensions of 600 by 600 by 90 mm. From each test panel, the Independent Engineer shall obtain six test specimens.

c) The Concessionaire shall perform preconstruction testing and inspections to include the following:

(i) Test each set of un-reinforced specimens for compressive strength according to BS EN 14487-1 or ASTM C1604.

(ii) Samples taken from test panel shall achieve a mean core grade of 2.0, in accordance with Section 1.7 of ACI 506.2, "Shotcrete Core Grades". In the event of failure, nozzleman shall be permitted one retest. Any nozzleman failing the second test shall not be permitted on the project.

(iii) The average compressive strength of all core samples from each test panel shall test to at least 100 percent of the strength specified for each specified age.

(4) Field quality Control

a) Control testing of the sprayed concrete shall be carried out in accordance with the requirement of BS EN 14487-1, Table 12 for Inspection Category 3 on test panels completed as part of the ongoing work.

b) The Concessionaire shall produce test panels, reinforced as in the structure, for each sprayed concrete mix at a frequency defined in BS EN 14487-1, Table 12 for Inspection Category 3. The test panels shall be produced with minimum dimensions of 600 by 600 by 90 mm. From each test panel, testing agency shall obtain required test specimens.

c) The Concessionaire shall conduct one Temperature Test per hour in accordance with ASTM C1064 when air temperature is 35 degrees C and above, and one test for each set of compressive-strength specimens.

d) The Independent Engineer may direct the Concessionaire to perform additional sampling and testing at no additional cost if any of the following occurs:

i. Core sample fails to show adequate bond with the ground.

ii. Core sample fails to show adequate bond between layers.

iii. Core sample shows obvious defects.

iv. Core sample does not meet the minimum strength requirements.

v. The Concessionaire shall install non-corrosive measuring pins at no greater than 1.5-meter centers in all directions to allow measurement of sprayed concrete thickness.

(5) Acceptance Criteria

(a) If the average strength of three cores from one area is less than the greater of 85 percent of the specified 28-day strength or 100 percent of the design strength, corrective work shall be performed, including application of additional thickness of sprayed concrete or removal and replacement of the defective sprayed concrete. Such corrective work shall be performed at no additional cost.

(b) Core Sampling: Cores shall be taken in accordance with the requirements of ASTM C1604 at locations randomly selected and at a frequency determined by the Independent Engineer if any of the field quality control testing in non-compliant. Cores shall have a length to diameter ratio of 1.0 or greater and shall be taken when the sprayed concrete is a minimum of 4 days old. If any cores taken show inadequate bond with the substrate, or between layers, show obvious defects or fail to meet specified compressive strength, two additional cores shall be taken within approximately 5 feet (1.5 metres) of the unacceptable core. If either of these cores show similar defects, the Independent Engineer shall direct the Concessionaire to remove the sprayed concrete in the surrounding area and replace it at no additional cost.

(c) Sprayed concrete which lacks uniformity, exhibits segregation, honeycombing, delamination or cracking, poor bond between layers or with the substrate or which fails to meet the specified compressive strength shall be regarded as defective sprayed concrete. The Independent Engineer reserves the right to order the removal of the defective sprayed concrete and its replacement with acceptable sprayed concrete or the placement of additional sprayed concrete layers to compensate for the inadequacy of the in-situ sprayed concrete material. The additional sprayed concrete shall be placed at no additional cost.

### 4.11.5 Rock Bolts and Dowels

#### 4.11.5.1Materials

(1) Rock bolts and dowels shall be manufactured from hot rolled deformed bars with a minimum steel grade of Fe 500, with the exception of areas to be excavated subsequently where glass fibre reinforced resin rods shall be used.

(2) Rock bolts shall have face plates which shall be of a dish shape in steel to the appropriate standard and shall have a hemispherical seating with centralized slot to suit the dimensions of the rock bolts.

(3) High quality cement shall be used for the grouting. The anchor shall reach 40 % of the characteristic bearing capacity (=Ptk according to BS EN 1537) after 6 hours and 100 % of the characteristic bearing capacity after 12 hours.

#### 4.11.5.2Manufacture of Rock bolts

(1) Rock bolts shall be manufactured from high yield deformed bar of appropriate diameter. The bar length shall be the required length of bar to be bonded to the rock with a due extra allowance for the cutting length including the threaded portion protruding from the rock as required for installation. One end shall be threaded with a coarse cut thread which shall not reduce the overall specified bar diameter by more than 3 mm. The other end shall be chamfered to facilitate installation.

(2) Face plates shall be of adequate size and thickness with a centralised slot to suit the dimensions of the rock bolts.

#### 4.11.5.3Manufacture of Dowels

(1) Dowels shall be manufactured from high yield deformed bar, with the exception of areas to be excavated subsequently where glass fibre reinforced resin rods shall be used.

(2) Dowels shall be either straight bars or shall have the protruding end bent to facilitate the specified connection between the rock and surrounding concrete or sprayed concrete when so required.

#### 4.11.5.4Testing of Rock Bolts

(1) Prior to installation of rock bolts in the Works, the Concessionaire shall carry out a series of tests as agreed with the Independent Engineer to prove the efficacy of the system and the Concessionaire 's capability to correctly install and tension the rock bolts.

(2) The tests shall demonstrate:

i) Number of resin cartridges required to provide the end anchorage with an applied load equal to the bar's characteristic strength and taking into account the over- length variation of holes.

ii) Number of resin or cement cartridges to fill the annulus around the rock bolt or dowel over the length of the hole between the anchorage and collar of the hole.

iii) Strength of the resin grout to fully anchor the bars up to the characteristic strength of the rock bolts.

iv) Capacity of the equipment to install the longest fully grouted rock bolts.

v) Equipment for tensioning the bolts to the specified loads.

vi) Capability of each crew to correctly install and tension the rock bolts.

(3) The Concessionaire shall undertake the tests with the equipment to be used in the Works.

(4) The Concessionaire shall provide a suitably calibrated direct tensioning jack and/or load cell of capacities in excess of the characteristic strength of the rock bolts. Loads and bolt elongations shall be recorded during the tests.

### 4.11.5.5Installation of Rock bolts and dowels

(1) The method of installation and tensioning of bolts must have a Notice to Proceed from the Independent Engineer prior to commencement.

(2) Unless otherwise proven acceptable by site trials, the rock bolts shall be installed in holes of diameter 10 mm to 15 mm greater than the maximum diameter of the rock bolt. The holes shall not be more than 100 mm longer than the grouted length of the rock bolt unless otherwise proven acceptable by site trials.

(3) The boreholes shall be cleaned out by flushing with compressed air or with clean water to remove all drill cuttings, sludge and debris prior to fixing the rock bolt. The amount of water flushing shall be kept to an absolute minimum. The installation of rock bolts shall follow the drilling and preparation of the borehole within 3 hours.

(4) Prior to the installation of the rock bolt, the entire borehole shall be completely filled with grout. This shall be done by filling the drilled hole from the bottom of the hole and withdrawing the grout hose slowly, always maintaining the hose embedded in the grout. A regular surface shall be provided to seat the face plate by trimming rock surfaces or forming pads of quick-setting mortar. Where mortar pads are required, they shall be of adequate thickness and extend beyond the face plate by 25 mm all round at that thickness before being chamfered at 45°. Care shall be taken to ensure that the mortar does not interfere with the installed bolt.

(5) The effectiveness of the rock bolt installation during tunnel driving shall be checked by testing a minimum of 1 per 100 installed bolts to a load corresponding to 80% of yield load. Should the assemblies fail at tensions less than 80% of the yield load of the bolt, the Concessionaire shall investigate the cause and take such remedial measures as may be necessary. Tests shall continue thereafter at a rate of 1 per 50 bolts until the Independent Engineer is satisfied that the cause of failure has been identified and adequately addressed.

(6) Regular calibration of tensioning devices shall be carried out by the Concessionaire.

### 4.11.5.6Records

For each rock bolt or dowel installed, the following information shall be recorded:

- reference number;
- type of installation;
- name of person taking record;
- date of drilling and installation;
- length and orientation of the drilled hole;
- length of installed rock bolt or dowel;
- tension applied to the rock bolt
- details of any tests carried out.

### 4.11.5.7Lattice Girders

#### 1. General

This sub-section applies to the supply and installation of the lattice girders required and used as support in underground excavations. The Concessionaire shall be solely responsible for the design and manufacture of lattice girders.

#### 2. General Requirements

a. Lattice Girders shall be effective as initial support immediately after excavation and shall subsequently act as reinforcement and load distributing members for the initial shotcrete lining.

b. The lattice girders shall be manufactured to meet the geometrical requirements for the excavation geometries including the construction tolerances for each rock class.

c. During transport, storage and handling of lattice girders, adequate measures shall be taken by the Concessionaire to prevent their bending, scraping, overstressing or any other damage. The damaged pieces shall not

be used in the works.

**3. Submittals**

Shop Drawings for the fabrication of the lattice girders shall be submitted for Notice to Proceed from the Independent Engineer prior to the commencement of the work.

The submission shall comprise the following:

i) Complete fabrication details of the lattice girders.

ii) Installation procedures and layout.

iii) Details of joints, connections, spacers, geometry etc.

iv) Certificates of compliance for the materials.

**4. Design of Lattice Girders**

a. Lattice girders are three-dimensional, lightweight steel frames manufactured of round or corrugated steel bars in compliance with the required excavation geometry of the tunnel.

b. Lattice girders shall consist of three primary bars, connected by stiffening elements as per the design. They shall be designed so as to:

i. Facilitate shotcrete penetration into and behind the girder, thereby minimizing the creation of projection shadows.

ii. Provide good quality bonding between the steel and shotcrete, to form a composite structure in the sense of a continuous reinforced shotcrete lining.

c. To ensure stability against buckling, the maximum spacing between stiffening elements shall be less than three times the cross-sectional height of the girder.

d. In case of fabrication on site, the Concessionaire shall submit a detailed method statement for obtaining a Notice to Proceed from the Independent Engineer.

e. The Concessionaire shall submit related detailed drawings of the lattice girders, showing also the number of sections in the frame and details of the connection between the sections. The details with appropriate calculation shall be submitted to the Independent Engineer for obtaining a Notice to Proceed.

**5. Materials**

a. Each of the primary bars of a lattice girder segment shall be composed of only one piece of high strength steel having yield strength of 500 MPa or more.

b. The connection elements at the end of lattice girder segments shall be constructed of angled structural steel having yield strength of 250 MPa or more, or of welded flat steel ensuring similar strength characteristics.

**6. Installation of Lattice Girders**

a. Lattice girder shall be installed to conform to the excavated shape. The geometry of Lattice Girders shall take into account the permissible inaccuracy of construction and tolerances of materials.

b. Lattice girders shall be erected to the lines and levels as required. The exact excavation levels will be determined by the Concessionaire suiting his equipment and construction method subject to a Notice to Proceed by the Independent Engineer.

c. Lattice girders shall be secured by use of spacers as well as temporary wood blocking or other appropriate means to maintain position during shotcreting.

d. Butt plates for steel girder segments and expansion unit in invert shall be provided as required. Tight connection of all elements shall be ensured such that the static efficiency of the cross section is maintained.

e. Lattice girders shall be embedded in shotcrete, in order to get contact between rock and lattice girder by a solid shotcrete packing which shall have a minimum cover to steel of 20 mm.

f. The lattice girders shall be erected perpendicular to the tunnel axis.

### 4.11.6 Fore poling

#### 4.11.6.1 General

Fore poling is a pre-excavation support element that may be required for tunnel excavation works. Fore poling shall

be applied in rock and soil conditions, which tend to produce over break, collapses or material inflows immediately following excavation. Fore poling may be applied locally or systematically as per the requirement for the safety of the works and to prevent over breaking. All fore poling must be fully grouted.

#### 4.11.6.2Material

(1) In case Boreholes are stable Steel pipes with a minimum outer diameter of 40 mm shall be used. Wall thicknesses of steel pipes shall not be less than 4 mm. Dowels (spiles) consisting of deformed high yield steel bars of grade Fe 500 with a minimum diameter of 32 mm may also be used instead of steel pipes, where found suitable.

(2) In case Boreholes are not stable Self-drilling bolts shall be used as fore poling elements where stability of the predrilled boreholes cannot be achieved, due to the encountered ground conditions. Self-drilling bolts shall be installed only if non-objected by the Independent Engineer and shall have a yield load of at least 200 KN. The grout used for self-drilling bolts shall be in accordance with the requirements specified by the bolt manufacturer. Grouting shall be carried out simultaneously with drilling to achieve a better grouting effect along the bolt.

#### 4.11.6.3Installation

(1) Forepoling shall be applied as shown on the drawings that have a Notice to Proceed from the Independent Engineer.

(2) Forepoling elements at 300 to 500 mm centres shall be inserted into the predrilled holes (steel pipes or dowels) at the face or drilled into the face (self-drilling bolts) towards the unexcavated ground.

(3) The length of forepoling elements shall be according to the design and drawings and shall be at least 1.50 meter longer than the excavation round length.

(4) Forepoling shall be used together with lattice girders or any other steel support system.

(5) Grouting of fore poling pipes and dowels shall be done with cement mortar, either before or after their insertion, as per the approved scheme.

(6) Forepoling shall be required to be properly supported by the lattice girder/steel sets and the shotcrete above the lattice girder/steel sets. Therefore, shotcreting of the gap between lattice girder/steel sets and rock in the portions of forepoling shall be completed only after the installation of forepoling.

#### 4.11.6.4Pipe Roof

A pipe roof is a special type of long forepoling (typically 9 – 15 m). The forepoling elements shall consist of steel pipes with a minimum outer diameter of 76 mm and a minimum yield load of 1200 KN. The length and spacing of the pipes shall be as per the design and drawings and as agreed by the Independent Engineer. The pipes shall be grouted with cement mortar.

### 4.11.7 Contact or Cavity Grouting

#### 4.11.7.1General

(1) Grout holes for contact grouting shall be drilled through any backfill outside the pipe and initial supports, where present, and into the ground.

(2) Grout holes for contact grouting shall be placed at a spacing not to exceed 5 metres unless otherwise non-objected by the Independent Engineer.

(3) For contact grouting, the maximum sustained grouting pressure shall be no more than 70 KPa above the maximum anticipated external hydrostatic pressure at the injection point, unless otherwise proposed by the Concessionaire, with the Independent Engineer's concurrence.

(4) Grout Mixes: Develop one or more grout mixes designed to completely fill the voids and to provide acceptable strength. Make four samples of each proposed grout mix and determine 24-hour and 28-day strength in accordance with ASTM C39 or C109. All grout mix proportions shall be subject to review and acceptance by the Independent Engineer.

#### 4.11.7.2Contact and Cavity Grouting Equipment

(1) Two pressure gauges shall be provided, one at the grout pump and one at the collar of each hole being grouted. The accuracy of the gauges shall be periodically checked with an accurately calibrated pressure gauge. A minimum of one spare pressure gauge shall be available on site at all times.

(2) Suitable stop valves shall be provided at the collar of each hole for use in maintaining pressure as required

until the grout has set.

(3) The grouting equipment shall be provided with a meter to determine the volume of grout injected.

(4) The grouting equipment shall be maintained in satisfactory operating condition throughout the course of the work to ensure continuous and efficient performance during grouting operations.

(5) Grout hoses shall have an inside diameter not less than 35 mm nor greater than 50 mm and capable of withstanding the maximum water and grout pressures to be used.

#### 4.11.7.3Cavity grouting for Tunnel Linings.

(1) For voids or cavities located outside tunnel or shaft linings (either segmental linings or in situ concrete linings) linings or other underground structures, the Concessionaire shall fill all cavities, voids and spaces remaining unfilled.

(2) Grout for cavity grouting shall be as described in Clause 3.12 above except where the Concessionaire may propose for the Independent Engineer's no objection that large voids are filled with other materials. The grout consistency shall be sufficiently fluid, but not more so, to ensure that the grout flows freely under low (less than 100 kN/m2) pressure into all parts of the space to be filled via grout pipes or grout holes provided for the purpose. Where appropriate, vent pipes shall be provided extending to the highest point of cavities.

(3) For in-situ concrete linings, cavity grouting shall be carried out not less than 28 days after a section of concrete lining has been poured.

(4) Holes shall be drilled through the concrete tunnel lining and into the cavity. The location and spacing of holes shall be the responsibility of the Concessionaire.

(5) Holes shall be re-drilled and re-grouted and further holes drilled until the lining is deemed to be completely grouted by refusal to accept further cavity grout.

(6) The Concessionaire shall ensure that grouting pressures do not result in ground heave or overstress or distortion of the lining or distortion or damage to other structures.

### 4.11.8 Water Tightness of Tunnel

#### 4.11.8.1Waterproofing Membrane

(1) For Non TBM tunnels, waterproof membranes shall consist of an impermeable heat welded sheet of one of the following materials: High Density Polyethylene (HDPE), soft Polyethylene Chloride (PVC), Ethylene Copolymerical Bitumen (ECB). The membrane as supplied shall be of such dimensions and shape as will result in the minimum of on-site seam welds. The loosely laid PVC sheet shall have a minimum thickness of 2 mm +/- 10%.

(2) The waterproofing shall be such that all underground structures with waterproofing are watertight. In case of leakage, provision shall be made for these to be repaired. In order to arrive at a projected tunnel service life of 100 years, the design life of the water proofing membrane shall be equivalent to tunnel design life.

(3) The membrane shall be manufactured in compliance to Bureau of Indian Standards, BIS 15909:2020 and other relevant guidelines.

(4) Fixing material, flashing, reinforcement for expansion joints, sealing flanges and preparation of corners and intersections shall be compatible with the waterproofing liner.

### 4.11.9 Geological Mapping & Rock Classification

#### 4.11.9.1General

(1) The purpose of Independent Engineering geological mapping is to record rock and rock mass conditions as encountered during excavation. The mapping and documentation shall enable the verification of the suitability of the designed support and excavation measures, the prediction of rock mass conditions ahead as well as the interpretation of results of the geotechnical monitoring related with ground deformations.

(2) The mapping and documentation of encountered geological conditions during excavation shall be based on a uniform legend and shall use uniform terms for the description of features which need to be recorded.

(3) In general, the mapping shall be performed to a scale of 1:100 or as suitable.

(4) Based on the follow-up mapping a vertical as well as a horizontal cross section shall be drawn, where the actual mapping results shall be incorporated continuously on a daily basis.

(5) The vertical section shall be located along the axis of the tunnel. The horizontal section may be fixed

according to the chosen sequence for excavating the tunnel cross section (full face, top heading - bench etc.). In case the tunnel is excavated by top heading – bench excavation sequence, the horizontal cross section shall be drawn at the level of the invert of the top heading. The scale could be between1:200 to 1:500; horizontal and vertical scale shall be the same.

### 4.11.10 Daily Records

Daily Reports shall be submitted and, in a format, non-objected by the Independent Engineer by 09:00 hrs. the following day for information.

## 4.12 SAFETY AND UNDERGROUND FACILITIES

### 4.12.1 Safety General

(1) Safety in the underground works shall be in accordance with BS6164 Code of Practice for Health and Safety in Tunnelling or other local standards at the time of Concession award. Where discrepancies exist between BS6164 and other local or regional standards the most onerous requirement shall be used.

(2) All tunnel machinery, with particular TBM's shall comply with the safety requirements listed in BS EN 16191Tunnelling Machinery Safety Requirements.

(3) Any relaxation to the clause 1 and 2 above in this section shall be non-objected by the Independent Engineer.

### 4.12.2 Underground Facilities

#### 4.12.2.1General

The Concessionaire shall submit descriptions of the installations he proposes to use for supply of water, ventilated air, compressed air, lighting, power supply, etc., and for the disposal of drainage and waste water, contaminated air, etc., for the Independent Engineer's Notice of No Objection in advance of starting underground works.

#### 4.12.2.2Telephone Communications

Telephone communications shall normally be provided between the working faces, portals and other areas where work is going on. Telephone locations shall be prominently displayed.

Telephone network should be provided for Independent Engineer office including telephone connection to the work's place and tunnel shafts.

#### 4.12.2.3Electric Cables

(1) All lighting and power cables installed underground shall be adequately insulated with joints made in a noticed manner. All installation and maintenance work shall be done by qualified personnel to a high standard. Cables shall be securely fixed above floor level with the exception of cables needed for occasional work.

(2) Separate circuit breaker systems shall be provided for the supply of power for equipment and for lighting, respectively, and they shall be kept well separated from signaling and telephone cables.

(3) Circuits used for firing explosives shall be kept separate from all other circuits by placing them on the opposite wall.

(4) All electric installations shall be adequately earthed in accordance with normal practice and local requirements and be noticed by the Independent Engineer. Installations shall furthermore be protected by earth-fault breakers, all in accordance with modern practice and safety standards and obtain a Notice of No Objection from the Independent Engineer.

#### 4.12.2.4Ventilation

(1) Pits, tunnels and headings shall always be kept ventilated to maintain an atmosphere fit for respiration and free from oxygen deficiency, potentially explosive or noxious gases and dust, whether present naturally or otherwise. Ventilation shall also be used to maintain a safe working temperature. Underground works shall be ventilated in accordance with all applicable regulations. Details of the proposed ventilation system shall be submitted to the Authority's Representative, for review, not less than 40 days prior to the start of commencement. Where more than one pollutant is present any adverse interaction between them shall be identified and mitigated. All diesel engines used in the underground works shall be provided with means, which shall be maintained in efficient order, of cooling exhaust gases and reducing the concentration of toxic gases to acceptable levels, filtering particulates and preventing emission of flames or sparks. In underground workings and in confined spaces the air breathed by persons shall not contain concentration of gases, vapors or dust greater than is safe for the . health or workmen, having regard to the effects of time, temperature, humidity and the combined effects contaminants.

(2) The Concessionaire shall install, operate and maintain a forced ventilation system in the underground works to enable the Works to be constructed in healthy, well-ventilated conditions. Dust shall be abstracted at or adjacent to the source.

(3) To minimise the dust hazard arising from drilling operations in rock excavations, all holes shall be wet drilled. Water sprays or atomisers shall be used to prevent dust rising including keeping the floors of haulage way damp.

(4) The Concessionaire shall submit to the Independent Engineer for his Notice of No Objection a full and detailed method statement detailing his proposed ventilation system, and where necessary cooling system, in the tunnels. The statement shall be accompanied by supporting calculations. The method statement shall be submitted at least 28 days before the start of any underground excavation.

(5) The ventilation system used during construction shall ensure that at all times a minimum oxygen content of 20 % by volume is available in any underground works. Furthermore, the minimum fresh air requirements given herein refer to the required ventilation conditions and additional provision shall be made to account for any losses, e.g. due to leaks in the ducts, for which the Concessionaire shall make provision in the ventilation calculations.

(6) The Concessionaire shall supply and utilize a hot-wire anemometer for the purpose of measuring air flows in the ventilation ducting.

(7) Instruments to register all the various noxious gases and dust shall at all times be available at the heading in good working order and condition. These shall be supplied and maintained by the Concessionaire, throughout the duration of the underground work.

(8) The Concessionaire shall be responsible for operating the ventilation system in the underground works until all his construction work is completed.

(9) The ventilation system in each section of the Works shall ensure that the following minimum air quantity requirements are provided at all times:

i) 0.3 m3/min for each person or worker in the underground works;

ii) 4.8 m3/min for each operating kW power of diesel plant, or equipment working in the underground works, based on 70% of the installed power being in operation at any one time;

iii) Sufficient to maintain an average air velocity of 0.5 m/s on every cross-section in working areas.

iv) Notwithstanding the above, the minimum quantity of fresh air delivered at the advancing face shall be 7 m3/s.

(10) The ventilation, and where necessary cooling, arrangements shall be designed to ensure a working environment such that:

i) at any time, the mean wet bulb temperature at all workplaces in anyone tunnel drive shall not exceed 27°C.

ii) similarly, the weighted mean wet bulb temperature at all workplace within 100 m of the advancing face of any one tunnel drive shall not exceed 27°C.

(11) To ensure compliance with the foregoing, the Concessionaire shall provide all necessary equipment to measure the wet bulb temperatures at regular intervals during each working shift or such other interval agreed with the Independent Engineer and ensure that suitable air coolers are available for use with the ventilation system at all times.

(12) The procedures shall be subject to a Notice of No Objection from the Independent Engineer.

(13) Maintenance of ventilation and cooling systems:

i) All equipment and ducting shall be maintained in sound working order at all times. Any damage to ducting shall be repaired without delay.

ii) Failure by the Concessionaire to comply with the requirements or to maintain the prescribed ventilation and cooling standards will entitle the Independent Engineer to order a temporary halt of all work within the affected area until the specified requirements are met.

(14) Use of internal combustion engine: No internal combustion engine other than a diesel engine shall be used in the underground works. Any diesel engine used in the underground works shall be provided with a means, which shall be maintained in efficient order, of cooling exhaust gases and reducing the concentration of toxic gases in the exhaust gases to acceptable levels and prevent emission of flames, sparks or pollutants.

(15) Notwithstanding the Concessionaire 's compliance with the above requirements for ventilation, the operation of all diesel engines in the underground works shall be discontinued and ventilation improved or other acceptable measures taken if any of the acceptable specified limits are exceeded.

(16) No diesel equipment shall be allowed underground if the exhaust gases contain more than 2,000 ppm carbon monoxide or 1,000 ppm of oxides of nitrogen.

(17) The engines of diesel-powered equipment underground shall not be kept running idle except while being tested or during brief halts while in use. No equipment shall be refuelled underground unless proper precautions are taken.

(18) Modification of ventilation system:

i) After excavation of any tunnel which will be lined, the ventilation system used for the excavation phase may have to be modified to allow for subsequent phases. Any such modifications, which shall be subject to a Notice of No Objection from the Independent Engineer, shall be allowed for by the Concessionaire in his design of the ventilation systems for the underground works.

ii) These allowances shall also include for increased localised ventilation during concreting and grouting operations and during the time that Concessionaire or others are carrying out welding or painting operations in the underground works.

iii) After concreting of linings, the ventilation system shall be so operated as to maintain satisfactory conditions for curing of the concrete.

**4.12.2.5Lighting during excavation**

(1) All underground areas where work is going on shall be illuminated with electric lights of adequate strength and number to allow work, inspection, mapping and surveying to be carried out in a proper and safe manner.

(2) Generally, the illumination on a horizontal plane at floor level shall be not less than 10 lux. At working faces (Tunnel face, excavation areas and crane lifting points), the illumination shall be not less than 100 lux. However, at other general working areas, the illumination shall not be less than 50 lux. Hand inspection lamps and electric battery torches shall always be available at working faces, together with emergency backup light for evacuation.

(3) Floodlighting on the site surface shall be adequate for the safe operation of the site. It shall be shrouded where necessary to ensure the light is directed to areas within the site, and to avoid nuisance. Lighting in the tunnel shall extend the full length and not be less than that required for safe working and access. Lamps shall be located with an interval of 25m. An alternative source of power and emergency lighting system shall be provided to allow emergency securing operations and evacuation safely in the event of a primary power failure. An adequate number of hand lamps shall be located at key points underground. The Concessionaire shall also provide suitable movable lamps to illuminate any area in Underground works including areas for instrumentation and where the Independent Engineer may wish to carry out inspection and rock mechanics tests or instrumentation.

(4) Lighting illumination by flame is strictly not permitted in the underground Works.

**4.12.2.6Dewatering**

(1) The Concessionaire shall keep all underground areas free from water by providing drains, ditches, pipes, pumps, sumps, etc. to drain water away. The Concessionaire shall submit to the Independent Engineer details of his proposals for dealing with water from any source prior to commencing underground work.

(2) In the event that gravity flow cannot be satisfactorily arranged, the Concessionaire shall remove the water by pumping and he shall provide, install, operate and maintain all necessary pumps, piping and other equipment required. The Concessionaire shall also provide sufficient numbers of standby pumps and generator to serve during periods of breakdown or maintenance.

(3) Where water bearing seams, fissures or broken ground is yielding undesirably large quantities of water, the Concessionaire shall grout such seams, fissures or broken ground to stem the same.

(4) The Concessionaire shall provide devices for measuring the quantities of water removed from underground excavations, by pumping or by gravity as the case may be. The Concessionaire shall provide certified calibration charts for all measuring devices and shall submit to the Independent Engineer a complete record of the quantities of water disposed either by pumping or by gravity and the times during which pumping has occurred.

(5) The Concessionaire shall provide water treatment facilities for wastewater disposal that satisfies the applicable environmental standards.

### 4.12.2.7Stand-by Generator

The Concessionaire shall provide Stand-by generator for emergency case, details of proposals for this system shall be submitted to the Independent Engineer for obtaining his Notice of No Objection.

### 4.12.2.8Noise control

(1) The Concessionaire shall take all necessary measures to minimise the impact of noise. Such measures shall include:

i) placing of covers over and around the source of noise.

ii) fitting adequately sized mufflers to ventilation and other noise generating equipment.

iii) erecting screens to separate the source of noise from the rest of the working area.

iv) use of electrically powered plant where possible.

(2) The Concessionaire shall provide a means of measuring the noise level and shall regularly calibrate such equipment. Measurements shall be taken regularly by the Concessionaire and a full report of readings made shall be submitted to the Independent Engineer within 24 hours. If in the opinion of the Independent Engineer noise levels are unacceptable or there are complaints from the local residents, the Concessionaire will take additional measures to restrict noise.

(3) The Concessionaire shall provide suitable ear protectors to his entire workforce and other persons on Site. Zones of risk shall be clearly identified with warning signs.

### 4.12.2.9Hot work

(1) Welding and burning operations (hot work) within the tunnel and upon the TBM or trailing backup system shall be kept to a minimum. Wherever possible, components shall be prepared on the surface and consideration given to alternative methods such as bolting and sawing/disc cutting.

(2) In addition to the above, hot work includes specialist operations such as conveyor belt vulcanisation procedures. Hot work may be undertaken provided the following measures are adhered to:

i) The relevant permits are in place.

ii) Only qualified personnel are permitted to perform hot work.

iii) All gas cylinders underground shall be stored and transported within steel protective cages.

iv) Gas bottles shall be fitted with flashback arresters.

v) A designated fire watch is in place and aware of his duties.

- One dry powder handheld fire extinguisher shall be available at the work location.

(3) A fire watch shall be maintained during burning operations. The fire watch shall have a fire extinguisher or fire hose readily available. The fire watch shall continue for a minimum of 30 minutes following the cessation of burning operations. When the maintenance teams do not change shift at the work area then all burning operations shall cease 30 minutes before the work area is vacated.

(4) Whenever it is necessary to carry out hot work in a confined space, a specially assigned person shall stand-by throughout the operation at the nearest point of entry. The stand-by person shall be equipped to give prompt assistance in the event of an emergency.

(5) Only one acetylene bottle and one oxygen bottle shall be permitted within the TBM and trailing backup system at any time. Upon job completion, gas bottles shall be removed as soon as possible.

(6) All welding sets, cables, connectors and terminations mounted upon the TBM or trailing backup system shall be maintained in a safe and serviceable condition. Earth returns shall be coupled directly to the item to be welded and to an independent earth in such a manner that the earthing path remains inside the protected work area. Pipes or vessels containing hydrocarbons must not be used for earthing purposes. Earth leads mounted upon the trailing backup system shall not be connected to hydraulic oil pipelines, motors, conduits, panels or switch panels. All supplies for welding equipment must be made with noticed cables and plug boxes and must be controlled from a circuit which includes protection sensitive to earth current security.

(7) Where stationary transformers are being used, a suitable switch shall be provided close to the equipment which allows for the isolation from the main supply.

#### 4.12.2.10 Safety notices

The Concessionaire shall obtain, erect and maintain adequate safety notices for underground work to satisfy statutory regulations and to the satisfaction of the Independent Engineer.

#### 4.12.2.11 Control of entry

(1) The Concessionaire shall establish and maintain effective systems to control access to the underground works by all persons. A system utilising the issue and retrieval of tokens or similar method shall be employed. The systems of control used by the Concessionaire shall obtain a Notice of No Objection from the Independent Engineer. The Independent Engineer reserves the right to withdraw his Notice of No Objection if he is not satisfied that the systems are being applied and enforced adequately.

(2) Where persons not normally engaged on the Works are authorised to enter the underground works, they shall at all times be accompanied by a representative of the Concessionaire or Independent Engineer.

(3) The Concessionaire shall also establish and maintain effective systems to control access to the TBM cutterhead, including electrical lockout procedures and obtain a Notice of No Objection from the Independent Engineer for the procedure.

#### 4.12.2.12 Compressed air working in cutterhead chamber

The Concessionaire shall submit for obtaining the Independent Engineer's Notice of No Objection. A method statement describing the type, capacity and arrangement of plant and medical facilities he proposes to install with full details of his decompression chamber, standby plant, power sources, air cleaning, air cooling plant, bulkhead and locking arrangements. The method statement should also describe the proposed system of signalling, communications and controls to be used in the compressed air operations.

#### 4.12.2.13 Stores, offices, workshops

The erection of stores, offices and workshops in the underground works, excepting those contained within the TBM backup, will not be permitted without the prior Notice of No Objection from the Independent Engineer.

### 4.12.3 Hazardous gas

#### 4.12.3.1General

(1) The Concessionaire shall continuously monitor the underground works for the presence of hazardous gas. Should hazardous gas be detected the level shall be controlled by dilution via the ventilation systems.

(2) For this purpose, the Concessionaire shall supply, use and keep in good order, sufficient equipment and apparatus to comply with the requirements specified hereunder. Where the term methane is used it shall be construed to mean any potentially explosive or hazardous gas.

#### 4.12.3.2Methane detection

(1) The atmosphere upon the TBM and trailing backup system, and NATM tunnel shall be constantly monitored for both the ingress of methane and oxygen levels.

(2) Regular testing for methane shall be carried out at each probe hole. Particular attention shall be paid for testing of methane when intrusive rocks are intersected by the probe hole.

(3) The Concessionaire shall provide a procedure and appropriate equipment to allow the safe re- entry and recommissioning TBM and trailing backup system following a gas-initiated power shutdown.

(4) Prior to the start of any shift, the person responsible for that shift shall test the underground works for the presence of methane and declare the area safe for excavation or otherwise.

(5) Inspection of tunnels is to be carried out on a weekly basis.

#### 4.12.3.3Ventilation equipment

(1) Ventilation equipment shall be provided in accordance with Clause 4.8.2.4.

(2) In the case of the tunnel boring machine, special attention shall be paid to ensuring that air is directed into areas of the machine and back-up equipment where methane may be trapped, and if necessary auxiliary ventilation equipment shall be provided.

## 4.13 AS-BUILT SURVEY OF ALIGNMENT

### 4.13.1 Objective

As soon as practicable after the completion of the tunnelling, the Concessionaire shall carry out an as- built survey of the tunnel alignment. The objectives of the survey are as follows:

(a) To confirm the position of every 5th ring of lining in case of bored tunnel and final support at every 5m in case of NATM tunnel, with respect to the theoretical alignment; this includes both vertical and horizontal geometry;

(b) To plot the positions of the rings/tunnel profile at points around the circumference(intrados) with respect to their theoretical positions;

(c) To produce an accurate record of the position of the tunnel with respect to the local infrastructure including building, utilities and other sure face physical features;

(d) To verify the finished alignment and profile of the as-constructed tunnel with respect to the theoretical alignment and design profile to ascertain compliance with the Concession provisions in this respect.

### 4.13.2 Procedure

(1) The Concessionaire shall carry out the alignment survey and determine the position, with respect to the theoretical tunnel alignment, of the leading edge of every 5th ring of tunnel lining (in case of bored tunnel) and finished tunnel profile (in case of NATM tunnel) at not less than 8 points on the circumference/profile. These shall be as follows:

a) tunnel crown;

b) tunnel invert;

c) axis left;

d) axis right;

e) 45º above axis left;

f) 45º above axis right;

g) 45º below axis left;

h) 45º below axis right.

(2) The Concessionaire shall take all necessary actions to ensure that the zones where measurements are required are clear of all construction-related obstructions.

Shafts shall be backfilled in layers not thicker than 250 mm each layer being thoroughly compacted with an appropriate compactor. The backfill material shall be homogenous with no material greater than 25mm in diameter. As far as practicable all extraneous materials such as steelwork and temporary timbers shall be removed as the backfilling progresses. Shaft linings shall be left in place to within 2.0mbelow finished ground level and the site reinstated with suitable granular material compacted as specified in Earthworks. Details of temporary works left in place shall be included in the as-built information and drawings. The Concessionaire ’s methodology for reinstatement of the works, infilling of shafts and adits shall be to the no objection of the Independent Engineer.

## 4.14 GROUND TREATMENT

### 4.14.1 General

(1) This Section describes requirements for ground improvement to facilitate launching and retrieving of the Tunnel Boring Machine (TBM), or any other facility utilizing grouting techniques, deep soil mixing, jet grouting or other procedures determined by the Concessionaire necessary to stabilise subsurface materials or to control the flow of groundwater into temporary excavations.

(2) The Concessionaire is responsible for all aspects of the design and implementation of ground improvement for:

(i) Stability of shaft excavations including walls and bases

(ii) Stability of ground during TBM break-in and break-out from shafts where specified or found necessary

(iii) Groundwater cut-off and inflows into shaft excavations

(3) The work includes mobilising equipment for grouting, determining suitable grouting procedures and grout mixes and control, containment of grout, and clean up.

### 4.14.2 Submittals

(1) The Concessionaire shall submit to the Independent Engineer for non-objection, a ground treatment design containing an evaluation of the hydraulic conductivity pre-treatment and the target permeability after the treatment and drawings showing the proposed grouting arrangement.

(2) The Concessionaire shall submit product information for proposed materials to the Independent Engineer for non-objection. Only non-toxic grouts and other ground treatment materials are acceptable for use.

(3) The Concessionaire shall provide a method statement and monitoring plan to the Independent Engineer for acceptance at least 4 weeks prior to the commencement of the particular grouting works. The method statement shall include, as a minimum:

- Details of proposed grout mixes, injection pressures and flow rates
- Maximum pressure and maximum volume
- Details of equipment to be used and other resources
- Proposed construction sequence
- Quality control measures with an Inspection and Test Plan as required to demonstrate compliance with the Specification and the Concessionaire 's design
- Methods for protection of utilities
- Health and safety procedures
- Risk assessment and proposed mitigation measures to reduce the risks to as low as reasonably practicable
- Material Safety Data sheets indicating mixing, handling, storage, and waste disposal requirements

The Concessionaire shall provide the Independent Engineer for information, a daily Ground Treatment Report to include the hole locations and ground treatment method for each location. Details shall include the following:

- Depth and diameter of drill holes
- Size, type and depth of casing used
- Diameter, sleeved length and un-sleeved length of any tubes installed in drill holes
- Quantity of sleeve grout used (if any)
- Quantity, type, pressure and gel time of grout injected at each injection point, or per metre length in the case of continuous grouting
- Monitoring and test results as specified
- Evaluations of the permeability post treatment.

## 4.15 EXECUTION

### 4.15.1 General

(1) Prior to starting work, all sub-surface services/utilities shall be located and protected and to the satisfaction of the appropriate authorities.

(2) Ground treatment, including any drilling works, shall be carried out with the utmost care to prevent disturbance to the nearby services and property. Care shall be taken to prevent ground loss or heave.

(3) The minimum offset from any drilled hole to a live utility shall be agreed with the respective utility owner and be provided within the method statement.

(4) If the Concessionaire encounters an unforeseen obstruction, he shall cease drilling and inform the Independent Engineer immediately. The methodology for continuing under such circumstances shall be addressed in the Concessionaire 's method statement.

(5) The Concessionaire shall establish suitable temporary benchmarks for the purpose of monitoring ground movements during ground treatment. Such benchmarks shall be outside the zone of influence of the ground treatment.

(6) The Concessionaire shall monitor ground movements due to ground treatment at least twice a day in accordance with requirements established in the Geotechnical Instrumentation and Monitoring contained herein.

(7) The maximum limit on surface subsidence or heave due to ground treatment shall be 50mm. The Concessionaire shall establish alarm and action limits to evaluate and modify ground improvement if required.

(8) In the event that surface movements exceed the specified maximum, the Concessionaire shall immediately stop work and propose alternative treatment methods such as, closer hole spacing, low viscosity grouts, reduced grout pressure, increased relief holes, etc., for the no objection by the Independent Engineer.

(9) If necessary, the Concessionaire shall inspect all manholes and inspection pits for services within 20 metres, with the permission of the appropriate authority, of any area where injection is taking place to ensure ground modifications effort are not impacting existing facilities.

(10) Inspection of manholes and inspection pits shall take place a minimum of twice per week during the period where ground modification is taking place. Should grouting material be found in any manhole, inspection pit, duct, pipe or other installation, the Concessionaire shall, under the direction of the Independent Engineer and with the permission of the relevant authority, remove ground modification materials. The Concessionaire shall propose alternate ground improvement methods to prevent further ground modification materials from accessing adjacent services.

(11) Proving of the improved ground shall be witnessed by the Independent Engineer and conducted from within launch a receiving shaft by measuring the flow from a hole drilled horizontally a distance of 3 metres beyond the outside wall of the temporary shaft. Calculations shall be submitted for the review of the Independent Engineer that correlate the measured flow rate through the probe hole to the estimated permeability of the zone of improved ground. The permeability shall not be greater than 1×10-6 cm/s for tunnel break-in or break-out activities to proceed. Should the permeability be greater than 1×10-6 cm/s, additional ground improvement measures shall be conducted until the permeability is reduced to a level that is acceptable to the Independent Engineer. The Concessionaire shall allow for all costs associated with testing in his Concession Price. No additional costs in respect of this requirement will be considered.

## 4.16 GEOTECHNICAL INSTRUMENTATION AND MONITORING

### 4.16.1 General

(1) The work specified in this section includes furnishing, installing, and monitoring geotechnical instrumentation for all underground works to be constructed, along with existing buildings, structures and services likely to be affected by the Works.

(2) The Concessionaire is responsible for identifying the zone of influence related to the work and shall determine the amount of additional instrumentation required, and locations to monitor.

### 4.16.2 Submittals

(1) The Concessionaire shall submit a Method Statement for the installation and monitoring of the Geotechnical Instrumentation and shall be submitted to the Independent Engineer for non- objection at least 60 days before commencement of instrumentation installation.

(2) The Method Statement shall include at a minimum:

a) Summary of the Concessionaire ’s methods and calculations use to determine the anticipated zone of influence associated with tunnel and shaft construction

b) Summary of the Concessionaire ’s assessment of the impact on third party infrastructure and the zone of influence of the works

c) Instrumentation and Monitoring requirements agreed with asset owners and provision proposed by the Concessionaire

d) Assessment of which parameters are to be monitored in order to safeguard third party assets and validate the Concessionaire ’s design e.g., ground movement, building/ structure movement, vibration, groundwater levels, etc.

e) The instrument types and specification

f) Planned depths, locations, and detailed drawings for all required and proposed instrumentation

g) The instrumentation layout and monitoring frequency

h) Protection of installed instrumentation, to minimise construction damage

i) The method(s) of instrument installation and calibration

j) Data collection process in the field

k) How data will be stored processed, and interpreted

l) Alarm and Action trigger levels for each class of instrumentation, including justification

m) Relevant Contingency Plans in response to when an Alarm or Action level has been exceeded

n) Flow chart identifying responsibilities and actions of key site personnel with contact details for key site staff in the event that an Alarm or Action level is exceeded

o) Proposal for group meetings to discuss instrumentation requirements and results, frequency of the meetings, and list of required attendees

p) All third-party interfaces confirming, name, organization, role, contact details and asset.

(3) The Concessionaire shall develop and implement a Movement and Settlement Control Plan to protect existing facilities, tunnels, utilities, structures, roads, streets, and other improvements from damage due to settlement or heave resulting from tunnel construction.

a) The plan shall be submitted for no objection to the at least 60 days before commencement of instrumentation installation.

b) The plan shall include the specific tunnelling methods that will be used to minimize loss of ground, procedures and instrumentation used for monitoring for loss of ground as specified herein, and ground improvement plans.

### 4.16.3 Quality Control

(1) The Concessionaire shall engage a professional, geotechnical instrumentation and monitoring firm, acceptable to the Independent Engineer to carry out the instrumentation and monitoring program. The responsible person shall have a minimum of 10 years' experience in geotechnical instrumentation and monitoring and his CV shall be submitted to the Independent Engineer for non- objection.

(2) The Concessionaire shall provide the following Survey Methods and Survey Control:

I. The Concessionaire shall establish deep cased bench marks from the approved datum for use in instrumentation monitoring.

II. The Concessionaire shall establish the elevations of deep cased bench marks by running level circuits started and closed at the specified bench mark and as follows:

a) Establish turning points so that foresights and back sights are approximately equal. Foresights and back sights shall be less than 60 m.

b) Turning points shall consist of well-defined surface points of solid objects or masonry nails driven into pavement.

c) Each error of closure shall be less than 0.3 mm. If any error of closure is greater than 0.3 mm, re-survey the circuit.

d) Prove the established elevations of deep cased bench marks by running at least three separate and complete level circuits which yield consistent results. Re-survey all level circuits until correct and repeatable elevations are obtained.

III. The Concessionaire shall determine initial locations and elevations of all monitoring points, instruments, and bench marks by optical surveying techniques.

IV. The Concessionaire shall prove initial readings of facility monitoring points by conducting at least three separate and complete sets of optical survey readings on each instrument which yield consistent results (plus or minus 0.3 mm).

(3) The Concessionaire shall provide the following for calibration:

(i) Calibrate all gauges and other instruments used for monitoring before use and provide copies of the calibration certificates to the Independent Engineer.

(ii) Calibrate all gauges and other instruments used for monitoring at appropriate time intervals and provide copies of the calibration certificates to the Independent Engineer.

(iii) Operation Requirements: All monitoring instrumentation shall be strong, durable, watertight, corrosion resistant, and able to remain stable under extreme temperature changes from 0 degree C to 60 degrees C.

(4) Testing:

(i) The Concessionaire shall demonstrate in the presence of the Independent Engineer within 7 days of

installation that the instrumentation is functioning correctly. Demonstrate that the central tube of any piezometer or inclinometer is clear to the full design depth. Perform rising and falling head permeability tests on all piezometers and an initial survey of inclinometer tubes to provide a baseline and to demonstrate that the tubes are clear.

(ii) During construction operations, the Concessionaire shall periodically demonstrate continued proper functioning of each standpipe piezometer by performing rising or falling head tests on a schedule approved by the Independent Engineer.

### 4.17 Blasting

These specifications shall be applicable for NATM, cut and cover and open ramp construction work, wherever permitted by the Independent Engineer.

a) Not less than 40 days prior to commencement of rock excavation in each area, the Concessionaire shall submit, for review by the Authority's Representative, details of the drilling and blasting methods which he intends to use in that area. If, at any time in a specific area, a plan which has been previously adopted does not these Specifications, the Concessionaire shall submit a revised plan to the Authority's Representative before continuing excavation in adjacent areas.

b) The Concessionaire shall develop controlled blasting techniques, which will satisfy the excavation requirements specified herein. In each different type of rock conditions, the Concessionaire's initial blasts shall be performed as trials, and the burden, drill hole pattern and depth, explosive type and quantity,· blasting sequence and drill delay pattern shall be modified to achieve the requirements specified herein.

c) Blasting means have to follow the licensing requirements and orders as well as the manufacturer's instructions.

d) Blasting operations shall be carried out only under the direction of an experienced operator. The Concessionaire shall appoint one competent person to be responsible for the security of explosives.

e) Blasting shall be carried out carefully so as to avoid loosening or shattering rock beyond the required line of excavation, and loose or shattered rock (where it does not contribute to stability of the excavation) shall be removed by scaling down or other means before personnel will be permitted to restart operations after blasting.

f) Notices of blasting operations shall be posted on site. Before each firing, the Concessionaire shall give audible warning, clear the area and shall take positive measures to prevent personnel from entering the danger area.

g) The Concessionaire shall monitor the results of the blasting closely and, where it is proper to do so, shall propose changes to his blasting operation for the agreement of the Authority's Representative.

h) Under no circumstances shall any holes be charged until completion of all drilling operations at the face.

i) After each blasting operation the tunnel drive shall be sufficiently ventilated to remove any nitrous gases and the atmospheric conditions shall be constantly checked prior to personnel accessing the excavated face.

j) No person shall be allowed to approach the face and no face operation shall commence until the Concessionaire's authorized person in charge of the operation has given permission after blasting round.

k) As soon as practicable after blasting and without undue delay the Concessionaire shall erect such support as may be necessary to safeguard the excavation and personnel.

I) The shot-firer must keep a record of the number of shots fired, their time of firing, type and weights of explosives used, and the type and number of detonators used, together with a record of the post-blast situation for each and every location. A copy of the record shall be available to the Authority's Representative at the end of every shift on which shots are fired.

## SECTION- 5

## SHAFTS AND PORTAL

### 5.1 Temporary Shafts

(1) The principal method of access for the erection, launching and retrieval of TBM together with the supply and removal of materials for the tunnelling works is expected to be from Launching or retrieval shafts.

(2) The Concessionaire shall be responsible for obtaining all appropriate approvals from the Relevant Authorities for all such works. No additional payment shall be admissible on this account for obtaining approvals as the Concessionaire is deemed to have accounted for the same in his tender/bid documents.

(3) Temporary access provisions for launching or retrieval shafts shall be designed and constructed to ensure the integrity of the temporary works and permanent structure at all stages of the Works and the water-tightness of the completed bored, NATM and Cut & Cover tunnels.

(4) The scope of work for additional temporary shafts shall include all the following.

(a) Any additional site investigation considered necessary by the Concessionaire to design and execute these works.

(b) All topographic, utility and building condition surveys.

(c) Analysis of potential ground movement effects and the design of measures to control such effects.

(d) Structural design of the shaft to meet the Concession requirements for cut and cover design.

(5) The Concessionaire shall ensure the compatibility of permanent and temporary Works designs and construction schedules and that construction interfaces, if any, are resolved.

(6) Temporary access shafts, where necessary, shall be retained with permanent structure for full height along the periphery of opening, backfilled with suitable material in accordance with the Concession. Temporary works shall be removed to 2 metres below original ground surface level, unless otherwise instructed, prior to full ground Reinstatement work. All affected roads, pavements and landscaped areas shall be fully reinstated.

(7) Where temporary shafts are required within or adjacent to road alignments such that the works for and operation of the temporary shaft may interfere with traffic on that road, the temporary shaft design shall aim to minimize long term traffic disruption at this location. The size, layout and period of occupation of road space at this temporary shaft shall be included in the Concessionaire's submissions to the Independent Engineer for Notice to Proceed. The design shall allow for all EBS as specified in these documents.

(8) No work shall commence on shaft excavation and support activities until the following submissions have been Non-objected by the Independent Engineer:

(a) Shaft Excavation and Support Method Statement.

(b) The Concessionaire ’s designs and method statements for temporary work shafts shall include as a minimum the following:

(i) Details and arrangements, method of assembly of the support system, materials, procedures, and equipment of any ground improvement required at work shafts to facilitate safe and effective exit and entry of the TBM

(ii) Method of preloading and bracing

(iii) Ground reinforcement details

(iv) Load test procedures

(v) Grouting materials and methods

(vi) Loads for various stages of bracing removal and concrete placement

(vii) Anticipated construction equipment loads

(viii) Maximum design load to be carried by the various member systems and preloads

(ix) Depths below the ground surface to which the proposed support system will be installed

(x) Maximum theoretical deflections of the support members and surrounding ground

(9) The Concessionaire before commencement of any shaft excavation shall also submit the following to the

Independent Engineer for Notice to Proceed,

(1) General arrangement of TBM drive sites and reception shaft sites showing layout of all temporary and permanent works, including site offices, stores, etc.

(2) Design submittals including calculations demonstrating that the design of the shaft support system will adequately support the shaft excavation throughout all stages of construction and until the shaft is either backfilled or a permanent retaining wall lining is installed within the shaft.

(3) Preliminary design drawings for temporary work shafts.

### 5.2 Shaft Support System

1. Excavation support system shall be designed to support ground and groundwater loads, utility loads, traffic and construction loads, and all other applicable surcharge to prevent damage to or minimise movement of existing buildings, structures and services. The Concessionaire shall ensure that the groundwater regime surrounding the shaft is not affected by the construction of the shaft unless the Concessionaire can adequately demonstrate that a temporary drawdown of the water table around the shaft will not cause any damage and or settlement to nearby buildings, structures and services.

2. Excavation support systems shall be designed to be compatible with the geological conditions described in the non-objected Geotechnical Interpretative Report completed by the Concessionaire.

3. Excavation support systems shall be designed for control of water, maintaining bottom stability and protection of subgrade.

4. The size, type, and design of the shaft excavation support system are the Concessionaire 's responsibility, and are subject to no objection by the Independent Engineer. The Concessionaire shall assume full responsibility for the design, construction, and safety of the shaft support system.

5. The system of support may consist of alternatives of secant pile walls, diaphragm walls, cast in-situ reinforced concrete walls or other Non-objected support system. Walls shall be secured in place as necessary with bracing members such as walers, ring beams, struts, tieback anchors, etc. Ground treatment, such as grouting, dewatering (if in non-compressible soils), freezing, etc., shall be used as necessary to stabilise loose ground and/or prevent groundwater ingress into shaft excavations.

6. Each support member shall be designed to support the maximum loads that may occur during construction.

7. The bottom of the support system shall be carried to an adequate depth below the main excavation to minimise lateral and vertical ground movements. Where additional excavation is carried below the main excavation, a means to control movement of the main excavation supports shall be provided.

8. The shaft shall be sized and the excavation support system designed to allow the required free space for the safe movement of workers, Concessionaire's Equipment, and materials in and out of the shafts.

9. If the proposed shaft support system includes tieback anchors, the Concessionaire shall provide the geotechnical profile for which each anchor is intended, the design load for the full depth of the excavation, the maximum design and proof loads, and the criteria proposed for deformations under proof loads.

10. If removal of the excavation support system is required wholly or in part, such removal shall be performed in a manner that shall not disturb or damage adjacent structures, construction, or utilities.

### 5.3 Invert Slab

The invert slab at each excavation shall be designed to protect the excavation invert in accordance with these minimum design criteria.

(1) Capable of resisting maximum hydrostatic uplift recommended in the non-objected geotechnical Interpretative Report completed by the Concessionaire, with a minimum safety factor of 1.5, either with or without a groundwater/pressure relief system. Reliance on pumping alone is not acceptable. Pump or power failure shall not result in unsafe hydraulic gradients, exceeding capacity of filters or excessive loads and deformation of shoring.

(2) Capable of supporting such combined dead and live loads as are required by the Concessionaire 's means and methods.

Shafts shall be partly open and partly closed which will be backfilled in layers not thicker than 250 mm, each layer being thoroughly compacted with an appropriate compactor. The backfill material shall be homogenous with no material greater than 25mm in diameter. As far as practicable all extraneous materials such as steelwork and temporary

timbers shall be removed as the backfilling progresses. Shaft linings shall be left in place to within 2.0mbelow finished ground level and the site reinstated with suitable granular material compacted as specified in Earthworks. Details of temporary works left in place shall be included in the as-built information and drawings. The Concessionaire 's methodology for reinstatement of the works, in filling of shafts and adits shall be to the no objection of the Independent Engineer.

## 5.4 Shaft Excavation in Rock

### (1) General

This section is applicable to construction of shaft and cut and cover section in rock, but not for excavation of bored and NATM tunnels in rock.

### (2) Excavation Method

1. The Concessionaire shall provide to the Independent Engineer full details of the proposed rock excavation methods for 'Notice of No Objection', at least 28 days before the commencement of excavation. Similarly, the Concessionaire shall submit his plans for methods for monitoring, particularly vibration adjacent to the EBS.

2. Blasting and other methods (where blasting is not permitted) such as mechanical, pneumatic or hydraulic plants or expansive chemical agents etc. are expected to be used in rock excavation.

3. Some of the methods that can be used are as follows:

a. Hydraulic Splitting: Splitter is a wedge assembly with mechanical magnification to produce the pump station Longitudinal thrust into transverse thrust, broken rock.

b. Hydraulic breaker: The power source of Hydraulic breaker can be excavator, loader or pump station which is mainly used to drive the hammer with power source to reciprocate the broken rock.

c. Static expansion: Static expansion agent is generally used as a main component of lime, the use of hydration reaction to release heat, the product is calcium hydroxide, the volume of expansion, relying on the hole to produce expansion pressure to break the rock or concrete.

d. Carbon dioxide cracker: The use of liquid carbon dioxide heat and gasification when the volume of rapid expansion of high pressure, so that coal, rock or concrete rupture.

e. Electrical Equipment: Plasma blasting is a method of using electric energy to excite the electrolyte solution into plasma so that material is oscillating

vigorously to produce high temperature and high pressure, forming ion cluster movement and rapidly forming shock wave to break the rock.

### (3) Rock Stabilization

1. The rock stabilization measures should be based on rock joint mapping result carried out by the Concessionaire and agreed by the Independent Engineer. The rock joint mapping results shall be kept on the Site and submitted to the Independent Engineer within 48 hours after the excavation. The name of the personnel who will carry out mapping shall be submitted to the Independent Engineer for Notice of No Objection.

2. The Concessionaire shall carry out rock stabilisation measures with minimum delay after the excavation of each round.

3. All rock stabilization proposals shall be submitted to the Independent Engineer for Notice of No Objection.

## 5.5 Backfilling of Shafts and Adits

(1) Temporary shafts and adits shall be completely backfilled on completion of the Works and water proofing of the RCC Structure. Backfill material shall be Grade M10 concrete covering 2m over the tunnel crown which may be placed either wet or dry. Adits shall be backfilled in sections working from the permanent Works.

(2) Temporary bulkheads shall be formed at agreed intervals and the upper part of the adit completely filled by grouting through pipes which have been installed into the adit roof. The bulkhead shall be moved back in stages until the whole of the adit is backfilled. Shafts shall be backfilled in layers not thicker than 250 mm, each layer being thoroughly compacted with an appropriate power rammer. The backfill material shall be homogenous; no large pieces of concrete or "plums" shall be used. As far as practicable all extraneous materials such as steelwork and temporary timbers shall be removed as the backfilling progresses. Shaft linings shall be dismantled to two metres below finished ground level and the site reinstated with suitable granular material compacted as specified in Earthworks. Details of temporary works left in place shall be included in the as-built information and drawings.

## 5.6 Portals

### 5.6.1 General

The practical function of a tunnel portal is to protect the road from rock falls and slides as well as against water. The aesthetical function of a tunnel portal is to provide a transition from the open landscape to a tunnel.

### 5.6.2 Construction details

Excavation of tunnel can commence from either side depending on the methodology as proposed by the Concessionaire. However, before commencement of works, it is recommended to drill bore holes by the Concessionaire at both the ends of tunnels. In case good rock is not available for construction of temporary shafts/access ramps for TBM launching further investigation shall be carried out to confirm the location from the concerning Dept/Authority/Independent Engineer-in-Charge.

To know the exact rock depth, it is recommended to drill bore holes by Concessionaire at the entrance & exit of the tunnels GAD Drawing Pre-bore holes shall be provided horizontally under the surface in the direction of the tunnel (this may have to be done in stages depending on the length of the tunnel) Ground support prior to excavating may include but not be limited to rock anchors, rock bolts, soil nails, canopy tubes or steel sets. Recommendations for special protection at shafts from falling rocks or boulders shall be provided.

Concessionaire shall drill bore holes to ascertain the good rock. In-case good rock not available the Concessionaire has to drill more bore to confirm the location of shaft from concerning dept/Authority/ Independent Engineer in charge.

### 5.6.3 Materials

The entry portal of Access tunnel should be constructed in Reinforced Cement Concrete (RCC) to protect the tunnel entry face from falling of loose overburden and to avoid any possible block of entry portion. The Concessionaire shall prepare and submit the method for construction of portal to the Independent Engineer for Notice of No Objection along with detailed Design Report including calculations schedules and drawings for each proposed excavation support wall/Portal construction. Ground support to finish portal surrounds may include shotcrete, masonry, stone or concrete blockwork, reinforced concrete, precast concrete panels and ground cover. insert a steel tube into the pre-bored hole and fill with grout. install a steel set at the portal to support the ends of the tubes (a steel set is a supporting frame constructed with steel I-beams).

### 5.6.4 Drainage and other Utility

The rainfall runoff from portal areas and roof discharge from mounted jet fans foundation shall be calculated at the portal for provision of discharge of water from portal area. A detail report shall be submitted by Concessionaire to Independent Engineer in charge. Approved quality PVC pipe is to be provided in abutments, piers, retaining wall, wing wall, return wall, wing wall of tunnel portals, parapets etc. including providing weep holes of 100mm dia. PVC pipe at 1.0m c/c horizontally and vertically, for all height and depths above/below ground level need to provided by Concessionaire.

Temporary support installed at the tunnel face and at the top heading invert level portion shall be remove after construction.

## SECTION – 6

## General Specifications

# 6 GENERAL

### 6.1 Introduction

These Specifications contained herein shall be read in conjunction with other Concession Documents.

The Indian and International Standards as scheduled below have been used as base for the specifications. The Outline Construction Technical Specifications are also based on latest edition of "Specifications for Road works" of Ministry of Road Transport &Highways (MORTH) as published by Indian Roads Congress. The Concessionaire shall be responsible for detailing in his specifications submitted to the Independent Engineer, as part of the Definitive Design Submission, the standards on which his materials and workmanship will be based. These shall be of similar or higher standard than those listed below. The Concessionaire is required to Notice in the first instance the Indian Standards and base the specifications on Indian Standards to the extent that they are applicable.

Alternative or additional codes and standards proposed by the Concessionaire shall be internationally recognised codes and shall be equivalent to or better than, Indian Standards issued by the Bureau of Indian Standards or any other Indian professional body or organisation, subject to being, in the opinion of the Independent Engineer, suitable for incorporation or reference into the specifications. The specifications have been divided into different sections / sub-heads for convenience only. They do not restrict any cross-references. The Concessionaire shall take into account inter-relations between various parts of works/trades. No claim shall be entertained on the basis of compartmental interpretations.

This Section covers Construction Specifications for all civil structures under the scope of this Concession.

### 6.2 Storing of Materials at site

**a.** All materials used in this Design and Build Project shall be stored on racks, supports, in bins, silos, godowns, under cover etc as appropriate to prevent deterioration or damage from any cause whatsoever to the entire satisfaction of the Independent Engineer.

**b.** The storage of materials shall be in accordance with IS 4082 "Recommendation on stacking and storage or construction materials on site" and as per IS 7969 "Safety code for handling and storage of building materials".

**c.** The materials shall be stored in a proper manner at places at site agreed by the Independent Engineer Should the place, where material is stored by the Concessionaire, be required by the Authority for any other purpose, the Concessionaire shall forthwith remove the material from that place at his own cost and clear the place for the use of the Authority within the time as communicated by the Independent Engineer and at no extra cost to the Authority.

### 6.3 Materials

All materials shall be of best quality and shall conform to relevant code of practice and manufacturer's specification. Wherever, no specific code of practice of IRC/BIS is applicable, the decision of the Independent Engineer shall be final and binding.

### 6.4 Workmanship

All works shall be true to level, plumb and square and the corners, edges and rises in all cases shall be unbroken and neat. Any work not to the satisfaction of the Authority or the Independent Engineer will be rejected and at the same shall be rectified or removed and replaced with work of the required standard of workmanship by the Concessionaire at no extra cost.

### 6.5 Load testing on Completed Structures

(1) During the period of construction or within the defect liability period, the Independent Engineer may at his discretion order the load testing of any completed structure or any part thereof if he has reasonable doubts about the adequacy of the strength of such structure for any of the following reasons.

a) Results of compressive strength on concrete test cubes falling below the specified strength.

b) Premature removal of formwork.

c) Inadequate curing of concrete.

d) Overloading during the construction of the structure or part thereof.

e) Carrying out concreting of any portion without the prior Noticed by the Independent Engineer.

f) Honey combed or damaged concrete which will affect the stability of the structure to carry the design load, more so in important or critical areas of the structure.

g) Any other circumstances attributable to the Concessionaire which may result in the structure or any part thereof being of less than the strength or performance required under the Concession.

(2) All the loading tests shall be carried out by the Concessionaire in accordance with the agreed methods and Standards. Such tests shall be carried out only after expiry of minimum 28 days or such longer period. The structure shall be subjected to a superimposed load equal to the specified superimposed load assumed in the design. This load shall be maintained for a period of 24 hours before removal. During the test, struts strong enough to take the whole load shall be placed in position leaving a gap under the members. The deflection due to the superimposed load shall be recorded by sufficient number of agreed reflectometers capable of reading to an accuracy of 0.02 millimeters and suitably located under the structure.

The structure shall be deemed to have passed the test if the maximum deflection at the end of 24 hours of loading does not exceed the deflection given by the following expressions:

D = 0.001 L2/25 T, where,

D = max deflection due to imposed load only

L = span of the member under load test (the shorter span in case of slabs). The span is the distance between centres of the supports or the clear distance between the supports plus the depth of the member, whichever is smaller. In case of cantilever, this shall be taken as twice the distance from the support to the end and deflection shall be adjusted for movement of the support.

T = depth of member.

If within 24 hours of the removal of the superimposed load, the structure does not recover at least 75% of the deflection under the superimposed load, the test loading shall be repeated after a lapse of 72 hours. If the recovery after the second test is less than 80% of the maximum deflection shown during the second test, the structure shall be considered to have failed to pass the test and shall be deemed to be unacceptable.

(3) In such cases the portion of the work concerned shall be taken down or cut out and reconstructed to comply with the specifications. Other remedial measures may be taken to make the structure secure at the discretion of the Independent Engineer. However, such remedial measures shall be carried out to the complete satisfaction of the Independent Engineer.

(4) All costs involved in carrying out the tests defined in this Clause (including load and integrity test for piles) and other incidental expense thereto shall be borne by the Concessionaire regardless of the result of the tests. In case of failure the Concessionaire shall take down or cut out and reconstruct the defective work or shall take the remedial measures, as instructed, at his own cost.

(5) If the load testing is instructed on any grounds other than mentioned in this clause, then the cost of the same shall be reimbursed if the test results are found to be satisfactory.

(6) In addition to the above load tests, non-destructive tests on various elements (except on piles) such as core test and ultrasonic pulse velocity test shall be carried out by the Concessionaire at his own expense. Such tests shall be carried out by an agency agreed with the Independent Engineer and. The acceptance criteria for these tests shall be as specified by the testing agency or good Independent Engineering practice subject to the Notice of the Independent Engineer.

### 6.6 Structural Work

(1) Unless otherwise specified, only controlled concrete with design mix and weigh batching is to be used for the work.

(2) Minimum cement content for various grades/elements of concrete as specified elsewhere in these specifications, is purely from durability point of view. Larger content of cement shall be provided if required by mix design or as per the requirement of relevant codes.

(3) Mix design using smaller aggregates of 10 millimeters and below shall also be done in advance for the use at the junctions, where reinforcement is congested.

(4) Procedure of mixing the admixtures shall be strictly as per the manufacturer’s recommendations.

(5) All the water tanks and other liquid retaining concrete structures shall undergo hydro- testing.

(6) Special benches shall be provided at site for stacking reinforcement bars of different sizes.

(7) Formwork for beams of Reinforced Cement Concrete works shall be designed in such a way that the formwork of the adjacent slabs can be removed without disturbing the props/supports to the beams.

(8) Wherever there are tension/suspended concrete members which are suspended from upper-level structural members, the shuttering/scaffolding of such members at lower level shall be kept in place until such time as the upper level supporting members have achieved the required minimum strength.

(9) The Concessionaire shall incorporate seismic considerations of anchoring and isolation in the design and detailing of the finishes. The element to be anchored shall have its motion suitably restrained and isolated so as not to be affected by the deformations/vibrations of the building during Construction.

(10) Formwork shall be provided for full height at all locations. Special precautions for such tall formwork shall be taken to ensure its safety and stability.

## 6.7 Piling

### 6.7.1 General: - Piling plant and Methods

(1) Not less than 2 weeks before any piling work is commenced the Concessionaire shall submit to the Independent Engineer for Notice of full details of his proposed piling plant, and detailed method statements for carrying out the Works. Such details shall include where applicable a full description of the piling frame, hammer, helmet and packing, methods of handling, pitching and supporting the piles before and during driving, the proposed driving procedure to obtain the required penetration, or the proposed set and the method of calculation of the specified working load of the piles and such further information as the Independent Engineer may require. Details of casings and concreting methods in respect of any driven or bored cast-in-place concrete piles shall be included in the submission.

(2) The Concessionaire shall not commence any piling until the plant and methods which he proposes to use have received a "Notice to Proceed" from the Independent Engineer but such a Notice shall not relieve the Concessionaire from any of his obligations and responsibilities under the Concession. If for any reason the Concessionaire wishes to make any change in the plant and methods of working, he shall not make any such change without having first obtained the Independent Engineer's "Notice to Proceed" for such changes.

(3) Reference shall be made to the following documents regarding matters relating to the safety of piling works

BS8004 Code of Practice for Foundations

BS5573 Code of Practice for Safety Precautions in the Construction of large Diameter Boreholes for Piling and Other Purposes

### 6.7.2 Records

The Concessionaire shall keep complete records of all data as required by the Independent Engineer covering the fabrication, driving and installation of each pile and shall submit two signed copies of these records to the Independent Engineer not later than 24 hours after installation of the piles.

### 6.7.3 Programme and Progress Report

The Concessionaire shall inform the Independent Engineer each day of the programme of piling for the following day and shall give adequate Notice of his intention to work outside normal hours and at weekends.

The Concessionaire shall submit to the Independent Engineer on the first day of each week, or on such other date as the Independent Engineer may decide, a progress report detailing the rate of progress to that date and progress during the previous week and/or period of all main items of piling works.

### 6.7.4 Setting Out

1. The Concessionaire shall establish and maintain permanent datum level points, base lines and grid lines to the Notice of the Independent Engineer and shall set out with a suitable identifiable pin or marker the position of each pile.

2. The setting out of each pile shall be given Notice by the Independent Engineer at least one day prior to commencing work on a pile and adequate Notice for checking shall be given by the Concessionaire.

3. Notwithstanding such Notice, the Concessionaire shall be responsible for the correct and proper setting out of the piles and for the correctness of the positions, levels, dimensions, and alignment of the piles.

**6.7.5** Tolerances

1. Piles

a) Piles shall be driven or bored accurately vertical or to the specified rake and the permitted deviation of the pile centre from the centre-point shown on the setting out plan shall not exceed 50 millimetres measured at the working level of the piling rig, or other level to which Independent Engineer has given Notice to proceed.

b) Deviation from specified cut-off level shall be 25 millimetres.

c) The maximum permitted deviation of the finished pile shall be 1 in 75 from the vertical for vertical piles, and for raking piles 1 in 25 from the specified rake.

d) Forcible corrections shall not be made to piles.

e) The manufacturing tolerances for precast concrete piles shall comply with the following requirements.

i. The external cross-sectional dimensions shall be within 0 millimetres and +5 millimetres of the specified dimensions.

ii. The wall thickness of hollows punconcrete piles shall be within 0 millimetres and +25 millimetres of the specified thickness.

iii. There shall be no irregularity exceeding 6 millimetres in a 3 metre length along the face of the pile measured using a 3 metre straight edge.

iv. The centroid of any cross-section of the pile shall not be more than 12 millimetres from the straight line connecting the centroids of the end faces of the piles.

v. The centroid of any cross-section of a hollow pile shall be determined by assuming that the pile has a solid section.

f) The diameter of cast-in-situ piles shall be at least 98% of the specified diameter.

2. Pile caps

a) Variation in dimensions shall be limited to +50 millimetres and –10 millimetres.

b) Misplacement in plan from specified position shall be limited to 15 millimetres.

c) Surface irregularity measured with 3 metre straight edge shall be limited to 5 millimetres.

d) Variation of levels at the top shall not be beyond 25 millimetres.

**6.7.6 Disturbances and Noise**

1. The Concessionaire shall carry out the piling work in such a manner and at such times as to minimize noise and disturbance.

2. The Concessionaire shall take precautions adequate enough to avoid damage to existing utilities and services and adjacent structures.

3. The Concessionaire shall ensure that damage does not occur to any part of completed piling works and shall submit to the Independent Engineer for Notice his proposed sequence and timing for driving or boring piles having regard to the avoidance of damage to adjacent piles.

**6.7.7 Obstructions**

If during the execution of the Works the Concessionaire encounters obstructions in the ground, he shall immediately notify the Independent Engineer accordingly, submit to him details of proposed methods for overcoming the obstruction and proceed according to the Independent Engineer's Notice.

**6.7.8 Drilling Fluid**

1. Drilling fluid shall comprise bentonite complying with Specification IS:2720-1965; IS:2911- 1979, Part I Section 2 Appendix A or DFCP 4 of the Oil Companies Materials Association or given Notice by the Independent Engineer and thoroughly mixed with clean fresh water to form a suspension meeting the specification requirements as submitted to and given Notice by the Independent Engineer.

2. The Concessionaire shall obtain manufacturers' certificates of the bentonite powder consigned to the site giving properties of each consignment and shall submit them to the Independent Engineer prior to commencing the work and whenever required.

3. The temperature of the water used in mixing the suspension shall not be lower than 5○C. Where saline or chemically contaminated groundwater occurs, special precautions to be maintained and brought to the Notice of Independent Engineer. Concessionaire to ensure and should take Notice to proceed from the Independent Engineer for any modification to the bentonite suspension or perhydrate of the bentonite in fresh water so as to make it suitable for pile construction.

4. The type and frequency of testing drilling fluid and the method and procedure of sampling shall be proposed by the Concessionaire and subject to Notice by the Independent Engineer prior to commencement of piling work. Such control tests on the bentonite suspension shall be carried out during the course of the piling work.

5. Before concreting a pile, the Concessionaire shall remove any heavily contaminated bentonite suspension which could impair the free flow of concrete from the tremie pipe. A sample of the bentonite suspension shall be taken from the base of the boring using a Noticed slurry sampling device and the specific gravity of the suspension should not exceed 1.20 as per standard practice and also as per IS:2911. Consistency of the mud suspension shall be controlled throughout the pouring as well as concreting operations in order to keep the hole stabilized as well as to avoid concrete mixing with the thicker mud suspension.

6. All reasonable steps shall be taken to prevent the spillage of bentonite suspension on the site in areas outside the immediate vicinity of boring. Discarded bentonite shall be removed from the Site without delay and any disposal thereof shall comply with the regulations of all appropriate relevant authorities.

### 6.7.9 Tension piles and ground anchors

a) Where tension piles or ground anchors are used the Concessionaire shall ensure that the load is correctly transmitted to all the tie rods or bolts.

b) The extension of rods by welding shall not be permitted unless it is known that steel will not be reduced in strength by welding.

c) The bond stresses of the rods in tension shall not exceed normal permissible bond stresses for type of steel and grade of concrete used.

## 6.8 Diaphragm Walling

### 6.8.1 General

1. The recommendations of BS 8004 Code of Practice for Foundation and DIN 4126 Cast-in- situ concrete diaphragm walls; design and construction shall be followed in so far as they are applicable to diaphragm wall construction. Similar Indian Standards for guidance or adoption are; IS 9556, IS 4651 and IS456.

2. The Concessionaire shall take full account of fact that in some locations the walls may be close to existing structures and/or within a location where headroom is limited.

3. The Concessionaire shall pay particular attention to safety aspects of the work, employing barriers and covers as necessary.

4. Where diaphragm walls form permanent structures, these shall also comply with all the requirements for reinforced concrete design and construction

### 6.8.2 Method Statement

1. The Concessionaire shall submit a method statement giving the full details of materials, plant and operations involved in the construction of diaphragm walls at least 4 weeks prior to the commencement of construction of diaphragm wall. This method statement shall include but not be limited to the following details.

a) Dimension of walls and lengths of panels.

b) Design calculation, dimensions and details of guide walls.

c) Formation of the joints between panels, including sealing the joints and installation of water stop.

d) Sequence of excavation and concreting of panels.

e) Methods of monitoring and checking the stability of adjacent buildings, structures properties, pavements, railways, services, utilities road furniture and the like, all termed EBS.

f) Methods of monitoring and checking the tolerances associated with the diaphragm wall panels.

g) Methods of monitoring and checking the stability of the diaphragm wall trench.

h) Mixing, transporting and placing equipment for the bentonite slurry.

i) the cleaning and re-use of bentonite slurry;

j) Method of disposal of contaminated bentonite slurry.

k) Type, source, chemical and physical properties of the bentonite to be used.

l) Calculations to show that the density of the bentonite and lowest head of slurry are sufficient to maintain stability of the trench, in ground conditions envisaged, to its entire length.

m) Methods of protection to any adjacent structure and utilities existing close to the trench.

2. Construction of diaphragm walls shall not commence until the Concessionaire ’s proposals have received a “Notice to Proceed” from the Independent Engineer

3. Unless otherwise given Notice to proceed by the Independent Engineer, the construction of panels shall be continuous once excavation has commenced. Excavated panels or part panels shall not be left open at night or during weekends.

### 6.8.3 Levels of Work

1. Diaphragm walls shall be concreted to the levels shown on Noticed drawings.

2. The effective trimmed final wall levels shall normally be taken as 250 millimetres below top of guide wall when concrete is cast-up to top of trench. If the groundwater table is high and if required cut-off is low and the groundwater table is also at depth, concreting can be stopped at lower level subject to the Notice of Independent Engineer.

3. Any remaining bentonite within the trench shall be displaced off using lean mix concrete, which shall be poured to the top of the guide walls.

### 6.8.4 Length of Panels

The length of the panels to be concreted shall be defined in the Concessionaire 's method statement and shall be subject to a “Notice to Proceed” from the Independent Engineer.

### 6.8.5 Tolerances

1. Construction shall be carried out in accordance with the following normal tolerances, unless otherwise defined by the Concessionaire 's drawings or procedures.

a) For straight or other specified profile panels, the minimum clear distance between the faces of the guide walls shall be the specified diaphragm wall thickness plus25 millimetres, and the maximum distance shall be the specified diaphragm wall thickness plus 50 millimetres. The guide walls shall be propped as necessary, to maintain these tolerances, and inner guide wall shall be constructed to the line as shown on the drawings.

b) The trench face of the guide wall on the side of the trench nearest to the subsequent main excavation shall be vertical to within 1:200. The wall face shall not vary from a straight line or the specified profile by more than +15 millimetres in 3 metres and shall be without ridges or abrupt irregularities.

c) The plane of the diaphragm wall face to be exposed shall be vertical to within a tolerance of 1:200, relative to a vertical line projected from the base of the guide wall. In addition to this tolerance, 75 millimetres shall be allowed for protuberances resulting from irregularities in the ground excavated beyond general face of the wall.

d) The ends of panels shall be vertical to within a tolerance of1:80.

e) Where recesses are to be formed by inserts in the wall, they shall be positioned within a vertical tolerance of ±75 millimetres, a horizontal tolerance measured along the face of the wall of ±75 millimetres, and a horizontal tolerance at right angles to the face of the wall as constructed of ±25 millimetres measured to the reinforcement cage.

f) The tolerance in positioning reinforcement shall be as follows.

i) Longitudinal tolerance of cage head at the top of guide wall and measured along the trench: ±75 millimetres.

ii) Vertical tolerance at cage head in relation to the top of the guide wall: ±50millimetres.

iii) Lateral tolerance of reinforcement position in the direction across width of the wall; ±25 millimetres.

g) The tolerance in positioning couplers and starter bars for subsequent structural connections shall be as follows.

i) Longitudinal tolerance measured along the trench, ±75 millimetres.

ii) Vertical tolerance, ±50 millimetres.

iii) Lateral tolerance in the direction across width of panel, ±25 millimetres.

h) A minimum cover to main reinforcement shall be 75 millimetres. Minimum clear distance between reinforcement bars shall be 100 millimetres.

i) Notwithstanding the requirements of this subsection the tolerances may be aggregated only to the extent that they do not exceed 250 millimetres.

2. If, during the general excavation, it is detected that the above-stated tolerances have been exceeded, the Concessionaire shall draw up proposals for remedying or compensating for the defects.

### 6.8.6 Access

The Concessionaire shall note the restricted access to portions of the Works and shall satisfy himself that his method of excavation, positioning of equipment, spoil handling, placement of reinforcement cages, stop ends, and concreting can be accommodated within these restrictions.

### 6.8.7 Adjacent EBS

1. The Concessionaire shall be responsible for any movement, distortion or damage resulting from his work to adjacent EBS.

2. The Concessionaire shall be deemed to have made due allowance in his rates and prices for all ancillary treatment and all work necessary to ensure the stability of all EBS that may be affected by his work.

### 6.8.8 Reinforcement

1. Reinforcement shall comply with the requirements of Section 2 of this Volume.

2. High strength deformed steel bars and wires for concrete reinforcement conforming to IS 1786- 1985 and structural steel sections conforming to IS 800-1984 shall be used.

3. Structural steel sections shall be inserted into the cage where openings shall be made at subsequent stages.

4. All reinforcement bars and other structural steel section used shall be clean and free from loose mill scales, dust, rust, oils, grease, paint or other coatings which may reduce the bond with concrete.

5. Front and rear of cages shall be marked on Site to identify them during placement, and lifting points and design of lifting lugs shall not cause distortion of the cage.

6. Distance spacers shall be of an agreed type, capable of resisting displacement during cage placement within the trench and shall not entrap slurry during cage placement or concreting.

7. The reinforcement shall be adequately fixed to avoid displacement and to maintain the minimum specified cover during concreting.

### 6.8.9 Concrete

1. Structural Concrete shall comply with the requirements of Clause 3.7 above.

### 6.8.10 Bentonite

1. Bentonite for use in the wall support slurry shall be in accordance with the requirements of this Concession.

2. The Concessionaire shall institute a programme of regular sampling and testing to ensure that the bentonite fluid properties are suitable for use in the Works. In this regard IS: 9556- 1980 shall be used for guidance.

### 6.8.11 Storage of Bentonite

1. Bentonite shall be stored in dry cool conditions. Particular care shall be taken with bulk storage to prevent balling of bentonite powder due to damp, or deterioration of properties due to damp and heat.

2. A suitable design of hopper cone and bentonite feeding device shall be adopted. IS 4082- 1996 shall be used for guidance regarding stacking and storage of construction materials and components at site.

### 6.8.12 Alternative Materials

1. The Concessionaire may, subject to the requirements of the Concession, consider and adopt suitable additional or alternative ingredients and additives for the wall support slurry to that of the bentonite specified above.

Samples and full details shall be obtained from the supplier and manufacturer of such ingredients.

2. Any such materials shall have no detrimental effect upon the stability of the excavation or concreting, or formed concrete immediate as well as long term.

3. Ingredients to counteract the loss of slurry to the surrounding strata shall be deemed covered by this Section.

### 6.8.13 Placing Concrete by Tremie

1. Tremie pipes shall be clean, water-tight and with a minimum internal diameter of 200 millimetres.

2. The tremie tube shall extend to the bottom of the trench excavation prior to concreting and care shall be taken to ensure that all bentonite slurry is expelled from the pipe during the initial charging operation. The tremie pipe shall be maintained with a minimum embedment of 2 metres into the concrete to prevent the re-entry of slurry into the pipe.

3. The Concessionaire shall ensure that an adequate supply of concrete to the tremie is available at all times so that placement is continuous until completion of the panel.

4. The number of tremie pipes per panel shall be in accordance with the method statement. Where more than one tremie pipe is employed during concrete pouring to any one panel, the charging of concrete into the pipes shall be arranged so that it is evenly distributed between the pipes and so that no differential head exists at the concrete/slurry interface over the length of the panel. This level shall be confirmed by soundings taken during the concrete pour.

### 6.8.14 Stop Ends

1. Stop-ends, inserted before placement of concrete in the panel, shall be clean and have a smooth regular surface. Any shutter release agent shall have no detrimental effect on the finished works. Where stop-ends are inserted in sections, adequate joint connections must be provided to ensure verticality over the whole length.

2. Extraction of stop-ends shall be carried out at such a time and in such a manner that no damage is caused to the concrete placed against them, or to the adjacent soil and structures.

3. Stop-ends shall be adequately restrained to prevent movement during concreting and not be permanently encased in the diaphragm wall

### 6.8.15 Inserts

Inserts shall be formed at the locations shown in the Concessionaire 's drawings and in accordance with his method statements and procedures.

### 6.8.16 Checking and Monitoring

The Concessionaire shall provide all necessary monitoring instrumentation necessary for the close and continuous checking of the movements and distortions of adjacent ground and EBS.

### 6.8.17 Safety and Emergency Procedures

The Concessionaire shall take all necessary precautions to ensure stability of his excavations and guide walls and shall take all necessary precautions and be responsible for the safety of personnel in the area of operation.

The Concessionaire shall maintain, available for immediate use, a sufficient quantity of slurry to allow for any sudden loss. The loss continues despite addition of the slurry and stability of the trench be placed at risk, the Concessionaire shall backfill with lean mix concrete to preserve stability of the trench and ensure safety of adjacent ground and EBS. The cause of the loss of slurry shall be investigated and works shall not recommence until remedial measures have been implemented.

### 6.8.18 Site Cleanliness

The Concessionaire shall ensure that the site is cleared of slurry and that surplus or displaced slurry is disposed of safely and without nuisance. All operations shall be conducted in such a manner as to minimize any spillage of slurry over the Site, or accesses thereto.

### 6.8.19 Obstructions

1. An obstruction is defined as material, the excavation of which hinders normal progress and the existence of which could not have been foreseen.

2. Upon encountering an obstruction, the Concessionaire shall determine the method to be employed in

removing the obstruction and such method shall be subject to the Notice of Independent Engineer

### 6.8.20 Disposal of Spoil

1. Spoil removed from the excavation shall be separated from the slurry employed in the excavation process. It shall be disposed of as quickly as possible to locations subject to Notice of the Independent Engineer and in such a manner that spillage and annoyance be minimised.

2. Contaminated slurry, not suitable for re-use, shall be removed from the site and disposed of.

### 6.8.21 Joints

1. All joints shall be fitted with a water-stop covering the full height of the wall.

2. Where concrete is cast against previously completed wall panels, the previously formed concrete shall be cleaned so that solid substances are removed before the joint is formed.

3. When the joint is exposed upon subsequent excavation, the Concessionaire shall immediately repair any joints which permit jetting or spraying of water or within which solid foreign substances greater than 3 millimetres separate the concrete in adjacent panels.

4. The walls and joints formed shall satisfy water-tightness requirements of this Concession.

### 6.8.22 Records

The following records shall be maintained and kept for each wall panel and such records shall be available for inspection by the Independent Engineer.

a) Name of work.

b) Panel No and reference drawing number.

c) Date and time of start and finish of panel excavation.

d) Details of any obstructions encountered; time spent and construction method adopted in overcoming such obstructions.

e) Date and time of completion of cage placement.

f) Date and time of start and completion of panel concreting;

g) Length of panel and width and depth of panel from top of guidewall

h) Top of guide wall level and densities;

i) Top level of wall as cast, in relation to top of guide wall at the edges and at the centre.

j) A log of soil type encountered from start to finish of excavation, and of slurry levels and densities.

k) Volume of concrete used and time of any interruptions in concrete supply where these exceed 15 minutes.

l) Volumes of normal and lean mix concrete.

m) Cut-off level of concrete below top of guide wall level.

n) Date, place and time of slurry control tests and results recorded.

o) Concrete test cubes, w/c ratio, slump markings, date and results obtained on testing.

p) Details of reinforcement and cage type.

q) Quantity of slurry removed from site and spoil removed from Site recorded by date.

r) A graph of theoretical and placed concrete volumes with depth.

### 6.8.23 Disposal of Slurry

Used bentonite or contaminated slurry not suitable for re-use shall be disposed of in water-tight containers. The Concessionaire may propose alternative means of disposal which shall be subject to Notice of the Independent Engineer.

## 6.9 Fabrication

(1) The work of fabrication shall comply with the requirements of IS: 800 or other relevant codes of practice Noticed to the Independent Engineer, in accordance with BS-EN 1993: 2006 or ASTM. Fabrication accuracy shall be

within the limits detailed in BS-EN 1993: 2006.

(2) All parts assembled for bolting shall be in close contact over the whole surface and all bearing stiffeners shall bear tightly at top and bottom without being drawn or caulked. The component parts shall be so assembled that they are neither twisted not otherwise damaged as specified cambers if any shall be provided. Drilling done during assembling shall not distort the metal or enlarge holes. The butting surfaces at all joints shall be so cut and milled so as to butt in close contact throughout the finished joints.

(3) Cutting shall be done automatically. Hand flame cutting will not be permitted.

(4) The edges and ends of all cut/sheared flange plates, web plates of plate girders, and all cover plates, and the ends of all angles, tees, channels and other sections forming the flanges of plate girders, shall be planed/ground.

(5) Holes for bolts shall be drilled to conform to clause 10 of IS:7215 (1974). Punching of holes will not be permitted. All drilling shall be free from burrs. No holes shall be made by gas cutting process.

(6) All welding for the works shall be carried out by first class welders and shall be in accordance with IS:816, IS:819, IS:1024, IS:1261, IS:1323 and IS:9595. The Independent Engineer may at his discretion order periodic tests of the welder and/or of the welds produced by them. All such tests shall be carried out by the Concessionaire at his cost.

(7) Safety requirements should conform to IS: 7205, IS: 7273 and IS: 7269 as applicable and should conform to safety, economy and rapidity.

(8) As much work as possible shall be welded in shops. The pieces shall be manipulated to ensure down hand welding for all shop joints as far as possible. All parts to be welded shall be arranged so as to fit properly on assembly. After assembly and before the general welding is to commence the parts are to be tack welded with small fillet or butt welds as the case may be. The tack welding must be strong enough to hold the parts together but small enough to be covered by the general welding. The welding procedure shall be so arranged that the distortion and shrinkage stresses are reduce to a minimum.

(9) All joints required in structure to facilitate transport or erection shall be shown on the drawings. The lengths of structural shall be the maximum normally available in the market and the jointing of shorter length in order to make up lengths required shall not be permitted.

(10) Each piece of steel work shall be marked distinctly before delivery, indicating the position and direction in which it is to be fixed. Three copies of a complete marking plan shall be supplied to the Independent Engineer before erection commences.

(11) In the case of welded fabrication any distortion remaining in the member after welding operations are completed shall be rectified by and/or at the expense of the Concessionaire.

(12) All members of trusses and lattice girders shall be straight throughout their length, unless shown otherwise on the drawings, and shall be accurately set to the lines shown on the drawings. Sheared edges of gussets or other members to be straightened and dressed where necessary.

(13) Templates and jigs used throughout the work shall be all steel. In cases where actual materials have been used as templates for drilling similar pieces, the Independent Engineer's Notice shall be obtained to use as parts of the finished structure.

(14) Apart from the requirements of welding specified under the above sub clauses, sections above, the Concessionaire shall ensure the following requirements in the welded joints.

(15) Strength-quality with parent metal.

(16) Absence of defects

(17) Corrosion resistance of the weld shall not be less than that of parent material in an aggressive environment.

(18) No gasket or other flexible material shall be placed between the holes. The holes in parts to be joined shall be sufficiently well aligned to permit bolts to be freely placed in position. Driving of bolts is not permitted. The nuts shall be placed so that the identification marks are clearly visible after tightening. Nuts and bolts shall always be tightened in a staggered pattern and, where there are more than four bolts in any one joint, they shall be tightened from the centre of the joint outwards.

### 6.9.1 Detailing of Connections

(1) Detailing of connections shall ensure that inaccessible pockets/gaps are avoided. In this respect, back-to-back

angles with spacers and similar details which would prevent full accessibility for painting are not acceptable.

(2) Where cope holes are required to allow completion of butt welding, they shall be of adequate size to allow fillet welding to seal the connection, while still allowing full accessibility for subsequent painting.

(3) Snipping of stiffeners at the root radii of rolled members is not acceptable. Stiffeners shall be cut to the required profile to fit closely into all such radii, and seal welded.

(4) High-strength friction grip (HSFG) bolts shall be used only on mating surfaces as specified herein.

(5) HSFG bolted connections, slip-bolted connections and welded connections shall not be used interchangeably or in tandem with each other. The use of each of these types of connections shall be separate and distinct.

### 6.9.2 Submissions

(1) The Concessionaire shall submit to the Independent Engineer two initial copies of each shop drawing and subsequently four copies of the final shop drawings for retention by the Independent Engineer.

(2) The Concessionaire shall submit for Notice details of erection procedures. The procedure should contain details of safety precautions to be taken during erection - refer IS 7205.

### 6.9.3 Welding

(1) Metal-arc welding of steel shall be in accordance with the requirements of relevant IS, BS-EN or ASCI standards.

(2) Run-on/run-off plates shall be used during butt welding.

(3) Fillet welds shall be continuous to form a complete seal where two members join or abut.

### 6.9.4 Electrodes

Welding consumables shall be suitable for the type of steel and position of welding and shall give a weld deposit with mechanical properties not less than the minimum specified in the relevant welding standards. Hydrogen-controlled electrodes shall be used for butt welding of steel over 25 millimetres thick.

### 6.9.5 Welders

Welders employed on the work shall be tested to BS 4871 and BS 4872: Part 1. Welding shall be carried out under the supervision of a competent welding technologist and the test pieces shall be tested to BS 4870.

### 6.9.6 Testing

(1) The Concessionaire shall make radiographic examination of butt welds in accordance with Section 8 of American Petroleum Industry (API) Standard 1104 and shall carry out dye-penetrant tests in accordance with BS 6443.

(2) Not less than 10% of the length of each butt weld shall be radiographically inspected and 10% shall be tested using the dye-penetrant method.

(3) Not less than 5% of the length of each fillet weld shall be tested using dye-penetrant testing.

### 6.9.7 Site Welding

(1) The Concessionaire may, subject to prior Notice, use site welding as an alternative to bolted connections.

(2) Site-welded joints shall be inspected by radiography in accordance with Section 8 of API Standard 1104 or by ultrasonic means when given Notice by the Independent Engineer. Initially 100% of each butt weld shall be inspected. At the Notice of the Independent Engineer, the number of inspections may subsequently be reduced.

(3) Finished welds shall comply with Section 6 of API Standard 1104. Defective welds shall be cut out, remade and retested as Noticed.

### 6.9.8 Erection of Steelwork

Erection of steelwork shall comply with the requirements of BS-EN 1993: 2006, Stanchions shall be plumbed using steel packs and wedges and restrained while the spaces beneath the base-plates are filled with a Noticed non-shrink cementitious grout. Packs and wedges shall be protected by grout to a minimum thickness of 50mm.

The Concessionaire shall be responsible for checking the alignment and level of foundation and correctness of foundation bolt centres, well in advance of starting erection work, and shall be responsible for any consequences for non-compliance thereof. Discrepancies if any shall immediately be brought to the Notice of the Independent Engineer.

The structure should be divided into erectable modules as per the total scheme. This should be pre- assembled in a suitable yard/platform and its matching with members of the adjacent module checked by trial assembly before erection.

Immediately prior to erection any rust in the paint area shall be removed by power wire brushing to a standard equivalent to SA3.

During erection the rough handling of fabricated materials such as bending, straining or pounding with sledges shall be avoided. Any damage to the structure during transportation or erection shall be immediately rectified by the Concessionaire at his own cost. The straightening of bend edges of plates, angles and other sections shall be done by methods which will not cause fracture.

Following the completion of the straightening, the surface of the member shall carefully be inspected for damage before further use.

The Concessionaire shall be responsible for accurately positioning, levelling and plumbing of all steelwork and placing of every part of the structure in accordance with the Noticed drawings and to the satisfaction of the Independent Engineer. All stanchion base, beam and girder bearings etc. shall be securely supported on suitable steel packs. All reference and datum points shall be fixed near the work site for facilitating the erection work.

All equipment used by the Concessionaire shall be sufficient for the purpose and for erection of steel work, in the time specified in Concession. Any lifting or erecting machinery shall be noticed to be removed from the site. If the Independent Engineer considers such appliances dangerous or unsuitable for their functions. Notice of Independent Engineer shall not relieve the Concessionaire from responsibilities for loads to which the erection of equipment shall be called upon to carry out. Adequate arrangement shall be made to resist wind loads and lateral forces arising at the time of erection.

The Concessionaire is entirely responsible for the stability of the structure during erection and shall arrange that sufficient tack bolts, braces or guy ropes are used to ensure that work will remain rigid until final bolting, riveting or welding is completed. The Concessionaire shall supply and fix, without extra charge, any temporary bracing which may be necessary.

All steelwork shall be erected in the exact position as shown on the Drawings. All vertical members shall be truly vertical throughout and all horizontal members truly horizontal, fabrication being such that all parts can be accurately assembled and erected. No permanent bolting, welding or grouting shall be done until proper alignment has been obtained and checked.

At stanchion splices and at other positions where concrete cover to the steel is liable to be restricted, bolts will be placed with their heads on the outside of the members.

All field assembly bolting and welding shall be executed in accordance with the requirements for shop fabrication excepting such as manifestly apply to shop conditions only. Where steel has been delivered painted the paint shall be removed before field welding for a distance of at least 50mm on either side of the joints. The number of washers on permanent bolts shall not be more than two for the nut and one for the bolt head.

### 6.9.9 Tolerances

The tolerances for erected steelwork shall be as shown on the Drawings. In-lieu of other information the tolerances from BS-EN 1993:2006 shall be adopted.

### 6.9.10 Bolted Connections

(1) Bolts shall be threaded only over the length of shank which is outside the parts bolted together. The bolt shall protrude by at least two complete threads and not more than four complete threads beyond the outer face of the tightened nut.

(2) Holes shall not be distorted or enlarged by the use of drifts.

(3) High strength friction grip bolts shall be fitted in accordance with BS 4604, Part 2.

(4) Load-indicating washers shall be installed in accordance with the manufacturer's recommendations.

### 6.9.11 Transportation and Storage

Steelwork and protective coatings shall be protected from damage during packing, handling, transportation and storage. The Concessionaire shall ensure that members are not subjected to greater stresses than those allowed in BS 5950, Part 2 during fabrication, transportation, storage and erection. Stored items shall not be in contact with each other and shall be clear of the ground.

### 6.9.12 Damaged Material

Steelwork deemed to be damaged during the Concession period shall be replaced. The Concessionaire shall provide Noticed by the Independent Engineer for remedial work to damaged material if repairable. The method of repair and final repaired condition shall be obtained a Notice by the Independent Engineer.

### 6.9.13 Galvanising

(1) Galvanising of steelwork, if required, shall be carried out after fabrication is complete. Steelwork required to be galvanised shall be pickled in dilute hydrochloric acid, washed, fluxed and stoved, and then coated with zinc by dipping in a bath of molten zinc.

Components shall be immersed in the bath only for the period sufficient to attain the temperature of the bath and shall be withdrawn at a speed which ensures that a coating of 610 grams per square metre of surface is achieved – i.e., 85 microns minimum Dry Film Thickness (DFT). Components shall be covered evenly on all surfaces. Items shall not be galvanised in more than one dip event due to potential warping or additional stresses that may be induced in the metal.

(2) Items described as heavily galvanised shall be grit or sand blasted prior to galvanising and shall receive a minimum coating of 1000 gram per square metre of surface – ie,140 microns minimum DFT.

(3) Lightweight gauge metalwork shall be galvanised by the hot-dip process as specified in BS 3083 or BS 2989.

(4) Contact between galvanised steel members and aluminium surfaces or between galvanised and ungalvanized steel members shall be prevented by means of Noticed insulating washers and grommets.

(5) Galvanised steelwork shall be cleaned, degreased and etch primed before application of the specified paint treatment.

### 6.9.14 Preparation of Steelwork for Protective Treatment

(1) Surfaces shall be cleaned to BS 7079 before any protective treatment is commenced.

(2) Steelwork shall be degreased and shot or grit blasted to Sa 2.5 quality standard with surface amplitude of 50 to 75 microns to remove rust and mill scale. Dust and debris shall be removed by vacuum cleaner, compressed air or brush. Site welds and adjacent steelwork shall be blast cleaned and similarly prepared. Surface defects shall be removed in accordance with BS 5950.

(3) Regular mill scale detection tests shall be made using the Copper Sulphate method.

### 6.9.15 Painting Generally

(1) Paint shall be applied by brushing or spraying in accordance with the manufacturer's instructions. When permitted, thinners shall be added to paint in strict accordance with the manufacturer's permitted percentages.

(2) Brushes stored in thinners shall be worked to remove thinners before re-use.

(3) Painting shall not be carried out when the steelwork temperature is below 4oC, above 50oC, less than 3oCabove the dew point, or when the relative humidity is above 80%.

(4) Stripe coats shall be applied to welds and steel edges before painting.

(5) Strong paint films shall be achieved on all cleats, arises, bolt holes, bolt heads and the like.

(6) Protective treatment, other than the site-applied coatings, shall be applied under factory conditions in an enclosed shop. Completed coats shall be checked for continuity by a low- voltage wet sponge holiday detector and for thickness by an Elcometer. The colour of each coat shall be sufficiently different to permit detection of incomplete application.

(7) If a required film thickness is specified, it shall be the minimum dry film thickness (DFT) as measured by a Noticed gauge. The gauge shall be calibrated for each coating by the use of a shim placed on the shot blasted blank or on the underlying coat. The shim shall correspond to the theoretical film thickness of the coating to be measured. Otherwise, a full coating shall be applied in accordance with the rate of coverage recommended by the manufacturer, having regard to the surface profile of the steel and the conditions of application.

(8) Sample plates shall be prepared for approval and shall thereafter be adopted as the standard to be achieved in the finished work.

(9) The Concessionaire shall prevent dust and dirt coming into contact with freshly painted surfaces.

(10) Before the site painting coats are applied, the surfaces shall be lightly abraded, if required by the manufacturer's instructions, and washed with clean water to remove salt and other impurities.

(11) Paint shall not be applied to the embedded portions of metal items except those within 75 millimetres of the finished concrete surface.

### 6.9.16 Application of Protective Layers

Blast-cleaned surfaces shall be kept dry and shall receive the first coat within 4 hours of the start of cleaning – i.e., 2 hours for outdoor blast-cleaning. They shall be treated in accordance with the protective treatment schedule, except the faying surfaces for high strength friction grip bolt connections.

### 6.9.17 Protection of Bolts etc.

Bolts, including high strength friction grip bolts, nuts and washers shall be hot-dip spun-galvanised or as Noticed by the Independent Engineer. The threads of nuts may be re-tapped as provided for in BS 729.

### 6.9.18 High Strength Friction Grip Connections

(1) Faying surfaces for high strength friction grip connectivity shall be blast-cleaned to Sa 2.5 quality standard, masked within two hours to exclude air and exposed just before bolting-up. Paint and other contaminants shall not be allowed on faying surfaces.

(2) Each consecutive coat of paint shall be stepped back from the edge of the faying surface by 15 millimetres.

### 6.9.19 Protective Treatment

(1) Damaged paintwork shall be blast-cleaned if bare metal is exposed or corrosion is present. If the first coat is intact the surface shall be prepared by power wire brushing. The prepared surface shall be protected with a nominated full paint protection system.

(2) Submerged steelwork shall, in addition, be coated with a compatible chlorinated rubber-based anti-fouling paint to a DFT of 75 microns.

### 6.9.20 Paintwork Executed on Site

(1) Following erection, the exposed parts of galvanised nuts, washers and bolts (except chain fixing bolts) shall be degreased, etch-primed and painted to the specification for adjacent steelwork. Freshly galvanised surfaces shall be abraded and washed before application of the etch-primer.

(2) After the preceding operations, and prior to the erection of cladding, if any, the Concessionaire shall apply to the superstructure steelwork the finish coat(s) as specified. Any damage to shop- coats will be made good on site prior to application of the Site coats. If steel has been exposed, then the area shall be blast-cleaned primed and receive all shop-coats or Site-coats to the required standard.

(3) Before the Site-coats are applied, the surfaces shall be lightly abraded, if required by the manufacturer's instructions, and washed with clean water to remove salt and other impurities. Paint shall not be applied to the embedded portions of metal items except those within 75 millimetres of the finished concrete surface.

## 6.10 RETAINING WALL

### 6.10.1 General Requirement

(1) Before commencement any construction work, the Concessionaire shall prepare and submit appropriate survey method statements relating to his proposed methods of working.

(2) The Concessionaire shall take into consideration all geological and other relevant parameters applicable for the Concession reach.

(3) Drainage treatment behind retaining walls shall be done. In principle, all walls should be provided with weep holes. The weep holes are placed horizontally at the lowest points where free outlets for water may be obtained and should be spaced at not more than 2.0 m center to center in a staggered manner. must be provided with filter material covered with geotextile filter fabric.

For rockfall following counter measures shall be followed by Concessionaire.

**TABLE 6.1: CLASSIFICATION OF COUNTERMEASURES FOR ROCK FALLS**

| SR. NO. | CLASSIFICATION | | TYPE OF WORK |
|---|---|---|---|
| 1 | Earth Work | Earth work | Removal |
| | | | Re-cutting |
| 2 | Drainage Work | Surfaced drainage | Drainage Ditches |
| 3 | Fixing Work | Supporting | Stone/ Concrete support |
| | | Anchoring work | Anchor/ Rock bolt |
| 4 | Slope Protection work | Pitching work | Stone / Concrete block |
| | | Shotcrete work | Mortared/ concrete |
| | | Crib work | Concrete block cribs (Precast) |
| | | | Cast in place concrete cribs |

### 6.10.2 Construction of Retaining Walls

Retaining walls should be carefully constructed because these structures are designed to retain the extensive earth pressure and therefore the failure of these structures will result in the severe damage not only to the road facilities but also to the road users.

(A) Foundation Work

The foundation works for retaining walls should be considered as follows:

(1) The bearing ground should be excavated to a depth required for placing a footing if it is bedrock, the excavated foundation surface of bedrock should be cleaned, and then the spread footing should be placed.

(2) If the bearing ground is earth or gravel, rubble stones should be laid over the excavated surface and rolled fully and uniformly, leveling concrete should be poured over the rubble stones, and then the spread foundation should be placed over it.

(3) If the bearing ground is soft and compressible, a pile foundation should generally be applied. In addition, if the soft ground (or stratum) is thin or if replacing material is easily available, the soft ground should be replaced with good quality soils so that the retaining walls may be built directly over the replaced material.

(B) Backfill Work

Backfilling should be not allowed until the retaining structure become stable and strong enough to resist the earth pressure.

(1) Only selected quality materials should be used to backfill the retaining wall.

(2) Compaction is completely required.

(3) Rain water should be completely prevented from flowing into the portion of backfilling.

(4) Drainage facilities must be provided in order to drain the seepage water. Especially weep holes must always be provided with a rate of one weep hole per 2-4 m2 of retaining wall.

In addition, in principle, anti-proof sand treatment behind the walls should be placed between the walls and the back slope or backfilling to prevent the flow out of fine soil from the back slope, and hence preventing from disturbing the stability of soil mass behind the walls.

## 6.11 BLASTING

**6.11.1** General

**Excavation Method**

(1) The Concessionaire shall provide to the Independent Engineer full details of the proposed rock excavation methods for Notice to Proceed at least 28 days before the commencement of excavation. Similarly, the Concessionaire shall submit his plans for methods for monitoring particularly vibration adjacent to the EBS.

(2) Since the area falls under the sensitive buildings and other important premises, Method such as mechanical, pneumatic or hydraulic plants to be used for shafts, Cross-passages /NATM in rock excavation.

(3) Usage of Blasting or expansive chemical agents etc. are subjected to Independent Engineer's issuance of No objection and approval from all the competent authorities for rock excavation.

**6.11.2** Definitions

"Controlled blasting" means that a designed drill and charging pattern has been Noticed and will incorporate one of the following techniques.

"Pre-splitting" means drilling a line of closely spaced parallel holes of appropriate diameter along the excavation surface, charging the holes with an appropriate amount of explosive and detonating these holes simultaneously, prior to the main production blast, to shear the rock along the line of drill holes.

"Smooth blasting" means the drilling of a line of closely spaced parallel holes along the excavation surface, with a suitable burden/spacing ratio, loading all the holes lightly with an appropriate amount of explosive and detonating all these charges simultaneously, after the detonation of the main production blast.

**6.11.3** General Requirements

(1) All blasting operations shall be conducted under the direction of a certified blaster. Evidence of blaster certification shall be carried by blasters or shall be on file at the Independent Engineer office during blasting operations. The blaster shall be present at the firing of a blast at all times.

(2) A blast design shall be submitted to the Independent Engineer for 'Notice to Proceed' prior to any blasting operations. The blast design will include sketches of drill patterns, delay times and blasting mats and shall indicate the type and amount of explosives to be used, critical dimensions, and the location and general description of structures to be protected, as well as an outline of design factors to be used, which protect the public and meet the applicable air blast and ground vibration standards. The Work shall be programmed so as to minimize blasting adjacent to previously constructed sections of the Works.

(3) Every precaution including the use of blast mats, timber boarding or other means shall be exercised to protect the Works and persons, animals and property in the vicinity of the Site. The Concessionaire shall accept responsibility for all injury or damage occasioned by any blasting operations and shall make good such damage without any additional payment.

(4) The Concessionaire shall, in particular, note the requirement that he must limit to the maximum extent practicable the spillage of material from surface excavations, whether by blasting or other means. To this end the Concessionaire shall take all necessary precautions including, if necessary, covering the rock prior to blasting with sufficient loose material to prevent the blasted material being thrown into the adjacent areas. If the Independent Engineer is of the opinion that insufficient precautions are being taken to minimize the spillage of material, he may instruct the Concessionaire to adopt further measures to reduce the spillage. No additional payment will be made to the Concessionaire for any such measures required and extension of time will not be granted.

**6.11.4** Use of Explosives

(1) Explosives shall not be used without Notice to Proceed from the Independent Engineer and only after the appropriate permits have been obtained. Notice to Proceed for blasting does not remove the Concessionaire 's liabilities or responsibilities to ensure that his method of blasting is safe and complies with all statutory and imposed limitations.

(2) A Relevant Authority will issue all blasting permits and related permissions pertaining to storage, transportation, control and use etc. The permits will include local/national requirements and other requirements of the International Fire Code and other international standards for explosive and blasting procedures, explosives training, blaster's handbook and safety practice manual etc. All explosives and related material shall be in conformity with the requirements of the Relevant Authority having jurisdiction and the specifications contained herewith. Blasting will not be permitted close to any building structure without appropriate monitoring systems and no objection from the Independent Engineer.

(3) Both cartridge and bulk explosives may be used where appropriate.

(4) Only sufficient explosives and detonators may be brought on to the Site for immediate blasting requirements. Explosives and detonators remaining unused after each blasting operation shall be disposed of, or removed from the Site.

(5) The Concessionaire shall appoint a Responsible Person or Persons to order and receive explosives on the Site. The name(s) shall be notified to the Independent Engineer.

(6) No persons other than those authorised by the Independent Engineer shall approach within 50m of the area being prepared for blasting, i.e. during charging and firing of the blast holes. The Concessionaire shall inform the Independent Engineer of the names of his authorised personnel and his method for excluding other

(7) The Concessionaire shall provide an agreed system of warning and preparing the general public and all Site personnel of an impending blast by both audible and visual means and shall ensure that the blasting area is cleared of all personnel immediately prior to blasting. This system shall comply with all statutory requirements.

(8) The limits for air-overpressure and vibration monitoring together with actions associated with the alert, alarm and action levels shall be addressed in the Blast Assessment Report/ Method Statement for the Notice to Proceed from the Independent Engineer.

(9) The Concessionaire shall use a lightning detector on site to assess the potential risk of lightning during delivery, loading and charging blast holes with explosives. The lightning detector shall be capable of detecting thunderstorms.

(10) The Concessionaire shall check for stray electric current at the blasting site prior to commencing charging.

(11) All blast air, exhaust gases and dust shall be filtered in an agreed manner before being ventilated into the air exhaust system. A detailed method statement will be required for seeking a Notice to Proceed from the Independent Engineer.

(12) Blast partition doors separating the Concessionaire 's Working Areas from the public and other operational areas shall be of adequate fire protection, water tightness, weight, thickness and density to effectively reduce the noise, water and dust transmitted from the Works and confine the effects of the blast to acceptable levels. The effective damping mass of the partitioning materials shall not be less than 30 kg/m2

**6.11.5** Delivery of Explosives

(1) The handling of explosives including storage, transportation and charging will be carried out in accordance with BS 5607, 'Code of Practice for Safe use of Explosives in the Construction Industry' and IS 10386 Part 4 'Handling Storage & Transportation of Explosives'.

(2) The Concessionaire shall submit his proposal for explosives collection and delivery for Notice to Proceed from the Independent Engineer. The risk assessment for the proposed arrangement shall be addressed in the Blasting Assessment Report.

(3) The Vehicle shall not carry more than 200kg of explosives at any one time or the figures agreed by the Independent Engineer. Upon each delivery of explosives, the Vehicle shall be escorted by the Concessionaire's appointed Responsible Person(s) and armed guards and as agreed by the Relevant Authority & the Independent Engineer.

(4) The explosive container shall be secured to the body of the Vehicle.

(5) At least two serviceable fire extinguishers shall be installed on the Vehicle.

(6) The Vehicle which has been fitted out to the above requirement is required to be presented for inspection and agreed with the Independent Engineer.

**6.11.6 Blasting Risk Assessment**

(1) The Blasting Risk Assessment and Blasting Risk Assessment Report shall be undertaken by a qualified Independent Engineer with the Notice to Proceed from the Independent Engineer.

(2) The Blasting Risk Assessment and Blasting Risk Assessment Report shall be carried out in accordance with the procedures submitted to and agreed by the Independent Engineer. The location and size of the blasting trials associated with the Blasting Risk Assessment shall have a Notice to Proceed from the Independent Engineer.

(3) The Blasting Risk Assessment shall evaluate the impact caused by blasting using gradual increase in vibration levels generated by trial blasts, which shall not exceed the specified values in the Concession. Planned vibration target levels generated by the trial blasts shall be obtained by adjusting explosive charge weights at the same time taking

into consideration changes in distance, drilling pattern, confinement of the blast and rock condition. The design of explosive charge weights shall be made from linear regression based on previous blasting works. The predicted PPV (not exceeding the specified values in the Concession) for each trial blast shall be made in accordance to a confidence level of 84%.

(4) After each trial blast a structural inspection of structures and tunnels shall be carried out to assess the effect of blasting induced vibration. The scope and extent of the structural inspection shall be agreed with the Independent Engineer. When no structural defects are reported the subsequent trial blasting may be increased to the next higher vibration target level, which shall not be exceeding the values specified in the Concession. Following completion of the Blasting Risk Assessment field works a Blasting Risk Assessment Report shall be required to be submitted to the Independent Engineer for Notice to Proceed. The Report shall include the followings as minimum contents:

- Drilling and explosive loading details for each trial blast;
- Delay plan for each trial blast;
- Charge weight per blast hole and charge weight per delay for each trial blast;
- Details of vibration monitoring instruments and geophone locations and orientation for each trial blast;
- Details of instrumentation and settlement monitoring for each trial blast;

(5) Graphical record of Elapse Time against Particle Velocity and Acceleration for each of the three orthogonal geophone directions for each trial blast for each filtering frequency used. All records are to identify the following: date, time, monitor, location, filtering frequency, channel number, channel maximum, project and trial blast identification; full wave form of the vibration measured on structures and installations showing; PPV, predominate frequency, displacement and acceleration;

(6) Maximum resultant peak values calculated by vector summation of the three orthogonal components of velocity and amplitude for the monitoring point closest to each trial blast at each filtering frequency used. Results to include distance from blast and range of the dominant vibration frequency;

(7) Results of structural condition survey conducted following each trial blast, and results of vibration monitoring and all other structures and buildings;

(8) Results of all trial blasts plotted as a linear regression defining constants for that site condition and the 50%, 84% and 95% confidence levels. Results to include dominant vibration frequency recorded.

### 6.11.7 Blasting Trials

(1) The Concessionaire shall submit to the Independent Engineer for Notice to Proceed full details of the blasting trials at least 14 days before the trials are carried out. Blasting trials shall be carried out for each proposed blasting procedure to demonstrate that:

- The procedure is safe;
- The dust and noise created are within acceptable limits;
- The resulting maximum peak particle velocity and maximum allowable vibration amplitude at locations stated in the Concession, or instructed by the Independent Engineer, can be satisfactorily predicted, recorded and demonstrated to be within the prescribed limits, and shall not adversely affect the safety and stability of adjoining structures, installations and land, facilities & equipment; and
- The specified tolerances for the final blasted surfaces and formations can be achieved.

(2) Blasting trials shall be carried out in accordance with the blasting procedure submitted to the Independent Engineer. The location and size of blasting trials shall have a Notice to Proceed from the Independent Engineer. These trials should not normally be part of the permanent works.

(3) Blasting trials shall be completed at least 7 days before the related main blasting starts.

(4) Blasting trials for pre-splitting and other methods of controlled blasting shall be carried out to form a face similar to the permanent works design. The blasting trials shall be carried out on rock which has similar properties to production blast areas and which is at least 6m away from any permanent excavated surface or at a distance agreed by the Independent Engineer.

(5) The blasting trials shall be sufficient to demonstrate the effectiveness of the Concessionaire 's proposed methods of blasting in all of the different areas of the blasting works.

(6) The blasting trials shall be conducted by qualified personnel with a Notice to Proceed from the Independent Engineer.

(7) If in the opinion of the Independent Engineer any aspect of the proposed blasting procedure as demonstrated by the blasting trials is unsatisfactory, particulars or proposed changes to the procedure shall be submitted to the Independent Engineer for Notice to Proceed; further blasting trials shall be carried out until the procedure is demonstrated to the satisfaction of the Independent Engineer.

(8) The results of all trial blasts shall be interpreted using regression analysis method. Regression lines together with all blasting data showing the relationship of peak particle velocity against scaled distance shall be plotted on logarithmic scale to define the site vibration constants for the 50%, 84% and 95% confidence levels. All subsequent main production blasting results shall be produced on the same plot, and the plot modified and updated, as appropriate to allow for the additional information. Separate trials are required for different blasting types and areas.

(9) Blasting shall not proceed until the Independent Engineer has issued a Notice to Proceed to the proposed blasting procedure.

(10) If changes to the agreed blasting procedure are proposed further blasting trials shall be carried out to demonstrate proposed changes are acceptable.

### 6.11.8 Blasting Schedule

(1) The Concessionaire shall submit a weekly schedule to the Independent Engineer advising the proposed dates, times and locations of blasting, in advance of each week.

(2) The Concessionaire shall confirm his intention to proceed with each scheduled blast to the Independent Engineer not less than 18 hours, nor more than 24 hours in advance of the predetermined time. The confirmation shall show the location of and the intended time of each blast and the name of the licensed blaster and shift foreman responsible.

(3) The Concessionaire shall distribute written notification to all organization's on Site 24 hours prior to undertaking surface blasting. Any delay or postponement of any blasts shall be notified to all organization's immediately

### 6.11.9 Vibration Due to Blasting

(1) Arrangements for installing instruments and taking measurements both inside and outside the Site shall be made by the Concessionaire.

(2) Measurement of vibrations generated by blasting shall be taken at locations proposed by the Concessionaire in his Blasting Assessment Report, Building Damage Assessment Report and Monitoring Proposal or as instructed by the Independent Engineer at all times when blasting is carried out. Records of the vibrations shall be kept by the Concessionaire on the Site and a copy provided to the Independent Engineer within 24 hours of measurement.

(3) Vibrations due to blasting shall be measured in terms of Peak Particle Velocity (PPV) and Vibrational Amplitude. The peak values shall be taken as the maximum resultant calculated by vector summation of the three orthogonal components of velocity and amplitude respectively measured as instantaneously as the resolution of the recording instrument permits.

(4) Measurements shall be made with seismographs of a type with Notice to Proceed from the Independent Engineer. The accuracy of seismographs shall be checked before blasting are carried out and shall be calibrated at least once a year.

(5) No blasting works shall be permitted without vibration measurements being recorded with approved vibration monitoring equipment mounted on a geophone pad which is rigidly bonded to form an integral part of the structure. If a production blast results in vibration amplitudes or peak particle velocity in excess of the specified limits, the Independent Engineer shall be notified immediately.

(6) The Concessionaire shall immediately check the fixing of monitoring equipment to confirm the reading accuracy and inspect the integrity of affected structures to ensure no immediate danger to the public and to implement remedial measures if necessary. No further blasting shall take place until measures to reduce the PPV and/or amplitude are adopted with a Notice to Proceed from the Independent Engineer.

(7) For structures in the proximity of blasting, the peak particle velocity shall be measured at the locations immediately adjacent to the structure nearest to the face being blasted or any other location where it is necessary to limit vibration.

(8) Vibration monitoring proposals shall be submitted to the Authority's Representative

(9) The measurement of peak particle velocity shall be obtained from instruments capable of measuring along three orthogonal axes, one of them shall be aligned parallel to the center line of the excavation and another shall be vertical. The Concessionaire has to provide supports for the measuring instrument if so, required by the manufacturer's instructions.

(10) The measurements of the particle velocities shall be the responsibility of the Concessionaire. Copies of the readings in an agreed form shall be supplied to the Authority's Representative.

(11) Prior to the commencement of blasting in any location, the Concessionaire shall demonstrate using test firings, or by other means, that neither the peak particle velocities given in the particular Standards and Specifications will be exceeded.

(12) The maximum allowable blasting vibrations shall be defined by the Concessionaire for every structure influenced with reference to the applicable Standards and Specifications for the relevant structure. The allowable blasting vibrations ·shall be approved by the Authority's Representative prior to any blasting operations.

### 6.11.10 Blasting Near Structures

(1) Blasting will not be permitted within 3m of the outside face of any existing underground structure. The Concessionaire shall propose alternative appropriate means of mechanical, pneumatic or hydraulic splitting for excavations at connections to existing structures for the Relevant Authorities' and Independent Engineer's Notice to Proceed.

(2) The Concessionaire shall be responsible for avoiding personal injuries and damage to adjacent structures from fly rock by erecting barricades and/or the use of blast mats or other means acceptable to the Independent Engineer. Should any damage be caused by his operations this shall be made good without any additional payment.

(3) The unrestricted use of explosives will generally not be permitted in any part of the Works. The amount of explosives that may be detonated shall not result in a ground vibration sufficient to damage the nearest point of any part of the Permanent Works to the blasting Site.

(4) In each and every case where the Concessionaire wishes to blast within 15 m of a structure, he shall prepare a proposal for this blasting and submit it to the Independent Engineer for a 'Notice to Proceed, no blasting work of this nature may be carried out without the Notice to Proceed from the Independent Engineer.

(5) The Concessionaire shall prepare a photographic record of each structure within 100 m of any Works, whether on the surface or underground, prior to any blasting taking place

### 6.11.11 Limits of Peak Particle Velocity and Vibration Amplitude

(1) The vibrations at structures and installations due to blasting measured in terms of peak particle velocity and vibrational amplitude shall not exceed the values stated in Table 6.2

Table 6.2 Restriction on PPV and Vibration Amplitude

| **Description** | **Max Allowable PPV (mm/sec)** | **Max Allowable Vibration** |
|---|---|---|
| Structures in "good" condition and Roads/Pavements/open areas | 25 | 0.2 |
| Structures in "fair" condition | 12 | 0.15 |
| Structures in "poor" condition and Heritage Structures/bridges and water supply structures | 5 | 0.1 |
| Fresh concrete: Less than 2 days old 2 to 8 days old | 5 | 0.1 |

| | | |
|---|---|---|
| more than 8 days old | 25 | 0.2 |
| | 50 | 0.2 |

(2) The Concessionaire shall submit calculations which demonstrate that the charge weights per delay period proposed at 84% Confidence Level do not exceed the vibration limitations stated in Table 6.2 to the Independent Engineer for Notice to Proceed. No blasting operations shall be carried out without Notice to Proceed from the Independent Engineer.

**6.11.12 Blasting: Tunnels and Shafts**

**(A) General**

(1) One probe hole shall be drilled ahead of every rock face for probing the ground conditions ahead prior to the blast hole drilling. Probing ahead shall be by impact or rotary drilling techniques, and is intended to detect any ground water or potential unstable soils, which may be treated by grouting techniques (ground treatment techniques)

(2) All blasting work for bulk excavation of tunnels and shafts shall be carried out using perimeter drilling and blasting techniques to control the geometry of and to

minimize any damage to the theoretical excavation profile and minimize geological over break.

(3) All charges shall be accurately made up and inserted into the holes at the correct spacing, and all holes shall be correctly stemmed and connected in the correct sequence with detonators being correctly delayed.

(4) If excavation by explosives is within 6m of the ground surface or an adjacent opening the Concessionaire shall modify his blasting pattern to reduce the over break and to produce the minimum amount of disturbance to the surrounding rock mass. Such Controlled Blasting shall incorporate, but may not be limited to, pre- splitting or smooth blasting techniques, decoupled charges and shall make use of explosives specifically manufactured for these purposes.

**(B) Controlled Blasting Tolerance**

(1) The Concessionaire shall carry out Controlled Blasting so as to achieve a final blast surface that exhibits a regular fracture plane between barrels without under break or over break greater than those which have been considered in deriving the theoretical excavation line and the required finished tunnel profile.

(2) If at any time the methods of drilling and blasting do not produce a uniform profile within the tolerances to achieve the required finished tunnel profile, no further blasting works shall be permitted until the Concessionaire establishes a technique that results in an excavation profile to the acceptable tolerances.

**(C) Blasting: Cross Passage**

(1) Screens and other protective covers as specified in the Method Statement shall be erected to prevent the projection of flying fragments of material resulting from blasting.

(2) Presplitting and other methods of controlled blasting shall be carried out in such a manner that the rock mass is cleanly split on the required plane such that the remaining rock mass is not shattered or loosened.

(3) Faces formed by presplitting or other methods of controlled blasting shall not exceed 1.5m in height in any one blasting operation or as agreed by the Independent Engineer.

(4) If at any time, any method of drilling and blasting does not produce a uniform final surface profile without over break, all within the required tolerances, the Concessionaire shall undertake further trials until a technique is established that results in an excavation profile to the acceptable tolerances.

**(D) Blasting Submittal**

(1) The following are minimum contents of blasting procedures that shall be submitted to the Independent Engineer for Notice to Proceed:

a. Any conditions or restrictions imposed by the Relevant Authorities, including copies of applications, licenses, permits and correspondence;

b. Names, qualifications and experience of the persons responsible for the design and supervision of blasting operations;

c. The roles and responsibilities of key personnel for blasting supervision shall be clearly defined on the Blasting

Assessment Report.

d. Location with survey control, diameter, inclination and depth of holes to be charged with explosive;

e. Type and total mass of explosive to be used and its mass and distribution in each hole;

f. Initiation sequence, delay periods and mass of explosive per delay;

g. Burden and bench height;

h. Ratio of diameter of explosive to diameter of hole;

i. Ratio of explosive charge weights to both volume and weight of rock to be removed by the proposed blast;

j. Arrangements for vibration monitoring system (e.g. relevant vibration and air overpressure monitory points) and methods of instrumentation and monitoring the effects of blasting;

k. Details of vibration monitoring system, including manufacturers literature and calibration certificates;

l. Methods of controlled blasting; and

m. Protective measures that have been agreed by the Independent Engineer to ensure there is no damage to surrounding property or equipment or EBS and to fully comply with the provisions of the Concession in this respect.

(2) Items (a) & (b) shall be submitted at least 30 days before blasting in a particular works area starts. Items (c) to (m) shall be submitted to the Independent Engineer at least 48 hours before the relevant blasting starts.

(3) The blasting procedures shall be reviewed as blasting continues and shall be updated to suit particular local conditions. When the procedures are required to be revised the Items (c) to (m) shall be submitted to the Independent Engineer for Notice to Proceed at least 48 hours before blasting starts.

**6.12 Explosives**

a) The Concessionaire shall use explosives only in circumstances where it is safe to do so having due regard to the safety of persons, third-party property and the safety of the Works. Explosives shall not be used without the agreement of the Authority's Representative.

b) The Concessionaire shall obtain all necessary licenses and consents and shall provide secure storage facilities for all explosives and equipment in accordance with Indian or International Standards Code of practice for the safe use of explosives in the construction industry and the requirements of the local Authorities and the Authority's Representative.

c) Explosives shall be handled and used only by the Concessionaire's duly authorized personnel. The names and qualifications of such personnel shall be submitted to the Authority's Representative in writing in advance of any possible use of explosives.

d) At an early stage, in advance of the proposed use of explosives, the Concessionaire shall notify the Authority's Representative, third parties, statutory authorities and services which have an interest in or are likely to be affected by blasting operations, of the general nature of the operation. The Concessionaire shall subsequently give a minimum of 14 days' notice to the Authority's Representative and others described above of the proposed use of explosives. With this notification the Concessionaire shall submit to the Authority's Representative a-detailed method statement on all aspects of the proposed 'use of explosives, including the treatment of misfires.

e) The Concessionaire shall comply with the following documents in respect of the use of explosives:

• Indian Explosives Act 1884

• Indian Explosive Rules 2008 and further amendment in Jan.2009

• The Manufacture and Storage of Explosives Regulations 2005

• BS 5607:1998 Code of practice for the safe use of explosives in the construction industry

• Control of Explosives Regulations 1991

• Carriage of Explosives by Road. Road Traffic (Carriage of Explosives) Regulations 1996

• PD CLC/TR 50426:2004 Assessment of inadvertent initiation of bridge wire electro-explosive devices by radio-frequency radiation. Guide Quarries (Explosives) Regulations 1988, as far as it is relevant to tunnel works

**6.13 Geological Mapping**

a) Geological mapping shall be performed by qualified geologists to provide a documentation of rock and rock mass condition encountered during excavation. -Additionally, all exposed rock surfaces of the open and underground excavations shall be washed down for inspection and geological mapping. Exposed rock surfaces at the required excavation pay lines shall be mapped after preparation but before shotcrete application. Tunnel and other underground faces shall be mapped just before the start of drilling. The Concessionaire shall allow in his construction procedure and schedule for the geological mapping Qf each tunnel face not less than 30 minutes.

b) The geological mapping shall include but not limited to the following information:

• excavation face

• tunnel meter

• geological unit

• intact rock:

• rock type and lithology description

• weathering and alteration degree

• uniaxial and unconfined compressive strength (from point load tests)

• rock mass:

o -jointing degree

o -geometry, orientation (strike and sip) and properties of discontinuities

o - face condition (homogeneous or heterogeneous)

o - water inflow

o -over breaks (separated in geological and non-geological)

o - ground response

o - suspected pervious zone

• the GSI value and the corresponding excavation class

• groundwater appearance

g) The Concessionaire shall provide lights, ladders, platforms and free access and shall assist the Authority's Representative to carry out inspection and geological mapping.

h) In case of sudden and unexpected changes of the geological conditions, the same shall be informed immediately to the Independent Engineer.

### 6.14 Exploratory Drillings

a) Long exploratory drillings with full core recovery shall be carried out when deemed necessary and required. Based on geological mapping and the exploratory drillings may require rock mechanic laboratory tests.

### 6.15 Excavation Cross Section Check

a) Tunnels will be constructed to the center lines as defined herein and subsequently agreed on site. Average deviation of the tunnel centerline from the design centerline, along a 100 m length of any tunnel section, shall not exceed 30 mm. If deviations in tunnels excavated exceed the specified tolerance, the Concessionaire shall be required to adapt his working methods so that the specified tolerances are achieved.

b) Immediately after excavation and before support installation the cross section of the actual round must be checked to avoid unexcavated ground reaching into the excavation area as per excavation and support category. The check must be done with proper instrumentation, either with free positioned theodolite or with temporarily installed monitoring device for profile check. When all ground material inside the excavation area is removed the support installation shall start earliest.

c) In case of partial excavation, the similar procedure shall be executed for each partial excavation.

### 6.16 Excavation Material Disposal

a) The disposal of excavation material shall be in accordance with specified compliance. Excavation material suitable to be utilized in the works shall be stockpiled separately from materials to be disposed. The use of excavation material

in the works shall agree with the Authority and IE.

b) Suitable materials shall, wherever possible, be transported directly from the required excavation to the various designated final locations.

c) Excavated materials, not suitable for or more than the construction requirements, shall be disposed of in spoil areas designated by the Local Authorities or the Authority's Representative. Unless otherwise provided for, spoil areas shall be built up in layers, with a maximum layer thickness of 0.5 m, and evenly compacted by the traffic of the construction equipment, aimed at minimizing future differential settlement. Final sloping and shaping of surfaces shall be as directed by IE. Other details of the work such as stabilization and drainage measures shall be as directed by IE.

d) All activity by the Concessionaire at spoils areas shall be confined to the limits designated by the Local Authorities or the Authority's Representative. The limits shall be clearly marked and, where directed barricaded to prevent traffic in areas outside the limits.

### 6.17 Urban Road Tunnel – Construction Phase: Comprehensive Disaster Management and Security Plan (CDMSP)

The construction of an urban road tunnel involves numerous inherent risks, including the possibility of structural collapse, underground fire, toxic gas release, flooding, and machinery accidents. To address such risks proactively, a Comprehensive Disaster Management and Security Plan (CDMSP) is mandated under Schedule D of the Concession Agreement. This document outlines a robust framework that the Concessionaire must adopt, focusing specifically on the challenges encountered during the construction phase of the tunnel. The plan emphasizes preparedness, prevention, mitigation, response, recovery, and coordination with statutory authorities, ensuring that construction proceeds with minimal risks to life, property, and environment.

#### 1. Objectives of the CDMSP (Construction Phase)

The CDMSP aims to create a safe and responsive environment for all stakeholders involved in tunnel construction. The specific objectives include:

a) Preparedness: Establish structured procedures and training mechanisms to ensure that all personnel can respond swiftly to any emergency.

b) Risk Minimization: Reduce the likelihood and potential consequences of disaster scenarios associated with underground construction.

c) Rapid Response: Ensure the immediate mobilization of trained personnel and resources to manage incidents effectively.

d) Protection of Life and Infrastructure: Safeguard human life and maintain the integrity of ongoing tunnel works and associated temporary structures.

#### 2. Key Components of the Disaster Management Plan

##### 2.1 Risk Identification and Assessment

Prior to commencing tunneling activities, the Concessionaire shall conduct a detailed risk and hazard assessment based on:

- Geological and geotechnical studies to identify fault zones, high groundwater levels, or unstable rock formations.
- Anticipated construction risks such as TBM entrapment, tool breakage, high-pressure blowouts, gas emissions, and collapse.
- Identification of potential human-induced hazards including electrical faults, equipment malfunction, fire, and human error.

A dynamic Hazard Risk Register shall be maintained and updated as new risks are identified during construction progress.

##### 2.2 Disaster Prevention and Mitigation Measures

Prevention and mitigation strategies must include:

- Installation of dewatering systems, sump pits, and submersible pumps to prevent flooding during excavation.
- Use of temporary ground support systems such as rock bolts, steel ribs, and shotcrete in weak strata.

- Deployment of multi-point extensometers, strain gauges, and tunnel convergence monitors to detect early warning signs.
- Provision of gas detection systems (methane, CO, H2S) with alarms and data logging.
- Redundant power supply systems to support ventilation, lighting, and communication during power outages.

**2.3 Emergency Preparedness**

- Dedicated Safety Officers will be present on each shift and shall have authority to halt operations in case of unsafe conditions.
- Safety and fire-fighting equipment including CO2 and dry chemical extinguishers shall be installed at intervals of 100 meters.
- Refuge chambers, fitted with compressed air cylinders and communication devices, shall be located at every 500 m interval.
- Routine mock drills and table-top exercises shall be conducted in collaboration with external emergency agencies.

**2.4 Incident Response and Management**

- A centrally located Emergency Control Unit (ECU) will coordinate all on-site emergency actions.
- Incident types shall be categorized (e.g., minor, major, catastrophic) and protocols developed for each, including chain-of-command and escalation levels.
- Emergency communication will be maintained through wired intercoms, mobile radios, satellite phones, and public address systems.
- Incident response kits shall include oxygen masks, stretchers, thermal blankets, and cutting/rescue tools.

**2.5 Evacuation and Rescue Operations**

- Designated evacuation routes with directional signage shall be created from working faces to surface escape points.
- Manual ladders and staircases shall be installed at intermediate shaft levels.
- Rescue teams trained in confined space recovery, first aid, and smoke diving shall be stationed at site.
- Emergency vehicles with stretcher arrangements must be stationed at tunnel portals for immediate transport to medical facilities.

**2.6 Recovery and Rehabilitation**

- After any major incident, a detailed incident analysis report will be prepared.
- Stability checks and certification of the affected tunnel section must be completed prior to resumption of works.
- Emotional counselling and medical rehabilitation support will be provided to injured workers.
- Documentation and learnings from incidents shall be incorporated into revised operating procedures and safety checklists.

**3. Construction Phase Security Measures**

In urban environments, construction sites are vulnerable to unauthorized access and vandalism. Security protocols must include:

- Perimeter fencing with barbed wire and illumination around all shaft locations and camps.
- Controlled entry through biometric or RFID-based access systems.
- CCTV surveillance with 24x7 recording and real-time monitoring.
- Appointment of trained security personnel on rotational duty.
- Incident coordination protocol with local law enforcement for intrusions, thefts, or sabotage attempts.

**4. Institutional Coordination and Monitoring**

- Formation of a site-level Emergency Response Coordination Committee (ERCC) chaired by the Project Director.
- Regular liaison with District Disaster Management Authority (DDMA), local police, fire department, and hospitals.
- Notification and communication systems integrated with a central project dashboard.
- Use of IoT-based wearable devices to monitor worker presence and health parameters inside the tunnel.

**5. Codal Provisions and Technical Guidelines**

The CDMSP shall strictly conform to the following standards:

| Standard/Guideline | Description |
|---|---|
| IRC SP:91-2019 | Indian Guidelines for Road Tunnels |
| NFPA 502 | Fire Protection Standards for Road Tunnels |
| IS 475:2021 | Indian Seismic Safety Standard |
| ISO 22320:2018 | Global Emergency Management Protocols |
| NBC 2016 | Indian Building Code on Fire Safety |
| PIARC Reports | Global Best Practices in Tunnel Safety |
| DGMS Circulars | Safety in Underground Construction |

**6. Documentation, Approval, and Review**

- The draft CDMSP must be submitted for approval to the Independent Engineer (IE) within 60 days of achieving Financial Closure.
- The plan shall be reviewed and updated every 6 months or following any significant incident or safety audit observation.
- A final version of the plan shall be appended to the project's Construction Environmental and Social Management Plan (CESMP).

**Section 7**

# 7 Electromechanical Works

## 7.1 General

### 7.1.1 Operation Philosophy

a) The Operations Control Centre for the tunnel is located at the Portal Ends of the Tunnel. The operation of the tunnel equipment shall be done in such a way that it operates fully automatically without intervention from the Control Centre. The Control Centre shall supervise the automatic operation and optimize the operation manually.

b) The work for all automatic processes shall be split on Programmable Logic Controls (PLC) and distributed I/O units for communication with connected PLCs. The local data transmission between the single equipment / appliances (like PLCs, distributed I/O units, etc.) shall be realized by use of an optical fiber cable "tunnel-ring". To this tunnel-ring every appliance for data transmission at the electrical rooms as well as tunnel Niches.

c) This modular architecture guarantees that the function of the whole system cannot be lost caused by a single defect unit and the supervision and control of the tunnel can be still done in an adequate way.

d) If an error occurs in one PLC or I/O unit, the operation of all other PLCs and I/O units must not be influenced by the localized fault.

e) If an error (wherever) in a communication service appears while the communication service cannot be made in a redundant way (for example if the optical fiber cables of the tunnel-ring are damaged due to construction works), the various controls on both sides shall continue their operation as standalone controls automatically.

### 7.1.2 General Information

a) These specifications shall be regarded as general specifications describing the required material, equipment, labour, etc. for the required installation such as Lighting, Ventilation, firefighting etc.

b) The Concessionaire shall check the accordance of the offered material, equipment, etc. with the requirements and standards presented in these specifications.

c) The Concessionaire shall make the shop drawings according to the material offered, equipment, labour, etc. where the actual values such as cable diameters, voltage drop, power, etc. shall be shown with the used material.

d) Therefore, the Concessionaire shall send detailed information of the material used (such as catalogues, instruction manuals, data sheets, etc.) to the Independent Independent Engineer for his approval.

e) All systems and products, which were offered by the tenderer, must be available in India.

### 7.1.3 Scope of works

a) The scope of tunnel electromechanical works include:

- 33kV System
- 11kV system
- 433/250 V – 50 Hz Power Supply
- Emergency Power Supply
- Earthing and Potential Equalization
- Tunnel Lighting
- Tunnel Fittings
- Fire Detection
- Telecontrol System / SCADA

### 7.1.4 Quality of Material and Workmanship

a) All goods, materials, plants and equipment incorporated in the permanent contract works shall be of approved reliability, well established design, of best quality of their respective kinds and shall comply with all relevant standards as given in this specification.

b) All plant and equipment shall be properly finished for the ambient conditions and circumstances of use.

c) The ambient temperature at site varies between 15 °C and 35 °C, and relative humidity varies between 55 % and 85%.

d) All equipment shall be with the approval of the Independent Engineer; the Concessionaire shall be responsible for any delays caused due to submission of unacceptable materials in connection with such approvals.

e) Wherever different materials are used, attention shall be paid to the electrochemical reactions (electrolytic corrosion) of these different materials (e.g. copper / steel, aluminum /steel and so on). However, suitable steps shall prevent any of these electrochemical reactions.

f) "Stainless steel " shall be 316 S 11 or 320 S 31 according BS.

g) Galvanized steel shall be used only when specified. "Galvanized steel" is always hot dip galvanized steel with zinc cover according to BS EN ISO 1461.

### 7.1.5 Paint

a) The colour of the paint shall be as per the decision of the Independent Engineer using standard RAL-colors.

b) Primary treatment of the metal: The surface of the metal shall be treated according to BS EN ISO 12944-4 (for steel the rust shall be removed).

c) Painting layer: 2 layers of primer, each of 40-micron thickness 2 layers of paint, each of about 60-micron thickness. The total thickness of the layers shall be about 200 microns.

d) Quality of paint: The paint shall be two component types with high latticed polymerization and low capillary development, adequate for tunnel atmosphere, resistant against salt water, high resistant against ultraviolet light, resistant against oil, acid and leach, insensitive against fat and free from heavy metal.

e) The temperature demand is from 0 °C to 120 °C.

### 7.1.6 PORTAL AND SERVICE BUILDINGS

Design, supply and install a complete lighting, power and communications system for the Portal

buildings for both the north and south portals and facilities area near South and North portals.

**General**

Carry out Testing and Commissioning of all electrical systems and components.

Carry out training of personnel.

Submission of Documentation.

Provision of As-Built documentation and manuals. Provision for sealing all penetrations.

Provision. of spare parts and associated storage cabinets. Provision of tools and associated storage cabinets. Carry out maintenance during the warranty period.

The Concessionaire shall be responsible for the following:

Co-ordination with other trades and supplying details to other trades to enable them to make the necessary provisions for the installation.

Coordination with other tunnel services Concessionaires and supplying details to those Concessionaires to enable them to make necessary provisions for the installation.

Provide and undertake all necessary modification, provisions and adjustments necessary to achieve the design intent as indicated on· the drawings and the specifications.

Liaise and coordinate with all authorities having jurisdiction.

Liaise and coordinate with Administration Building Services Concessionaires.

Work not to be executed under this section of the contract, by the E&M Concessionaire (not under this scope). Note specific clarifications and exceptions

The following work will be carried out by other sub Contractor:

Major penetrations and trimming etc necessary to accommodate the works. Masonry risers/ shafts for exhaust /supply air.

Niche required for equipment installation.

Provision of floors drains and sump pits as required in plant rooms. Installation of rock bolts.

Plinths for major equipment as required

### 7.1.7 Lightning Protection

a) The Concessionaire shall take all the necessary and adequate precautions against influences and damage, which may occur due to lightning strikes in the region on all of the electrical equipment.

b) All low voltage and communication metallic cables entering the Service Buildings, electrical rooms or the Control Centre shall be protected against over voltages with special surge arrestor banks for control cables.

c) The Concessionaire shall provide all measures of lighting protection and shall obtain the approval of the engineer and the employer.

### 7.1.8 Ground and Bonding

a) All exposed metal work and metal which is not current-carrying part of the electrical circuitry, including equipment enclosures, panels and supports shall be bonded together and to ground. Substantial non-ferrous ground lugs or studs shall be fitted for bonding cable shields or other adjacent equipment.

b) Where sections of distribution cabinets / panels shall be placed together to form a composite unit, a bonding strip shall be provided through the intermediate sections to provide a complete bonding between all sections.

c) The connections of grounding and bonding shall be stud- or clamp- type.

d) These requirements shall apply irrespective of the operating voltage and purpose of the equipment.

e) All required suppression chokes / filters shall be included and shall be capable of withstanding faulty conditions. All cable shields shall be bonded together and shall be connected to the ground electrode. Particular attention shall be paid to the correct bonding and grounding of single core cable shields.

f) The Earthing bus bar for Electromechanical Installations shall be permanently connected to the main Earthing bus bar.

### 7.1.9 Submittals

a) Working detail drawings and descriptions of materials and equipment shall be submitted and shall include sizes, details and arrangements of numbers, method of assembly and testing, lists of materials and such other data as required permitting to the engineer to check the adequacy of the proposed installation.

### 7.1.10 Standards and Regulations

a) Standards and regulations of the following organizations shall be applied for the completion of the works wherever applicable as applicable at the time of execution of works.

b) Indian Standards

| Standard | Title |
|---|---|
| IS 13118 | Specification for High-Voltage Alternating-Current Circuit-Breakers |
| IS 13118 | Specification for High-Voltage Alternating-Current Circuit-Breakers |
| IS/IEC 60947-3 | Low voltage switchgear and control gear: Part 3 Switches, disconnectors, switch-disconnectors and fuse combination units |
| IS/IEC 60947-3 | Low voltage switchgear and control gear: Part 3 Switches, disconnectors, switch-disconnectors and fuse combination units |
| IS 3427-1997 | A.C. Metal Enclosed Switchgear and Control gear for Rated Voltages Above 1 kV and up to and Including 52 kV |
| IS 5082 | Wrought aluminium and aluminium alloy bars, rods, tubes and sections for electrical purposes |
| IS 1897 | Copper strip for electrical purposes - Specification |
| IS 8084 | Interconnecting bus bars for ac voltage above 1 kV up to and including 36 kV |
| IS 5578 | Guide for marking of insulated conductors |
| IS 11353 | Guide for Uniform System of Marking and Identification of Conductors and Apparatus Terminals |
| IS 2705 PART1 | Current transformers: Part 1 General requirements |
| IS 2705 PART2 | Current transformers: Part 2 Measuring current transformers |
| IS 2705 PART3 | Current Transformers : Part 3 Protective current Transformers |
| IS 2705 PART4 | Current transformers: Part 4 Protective current transformers for special purpose applications |
| IS 3156 PART 1 | Voltage transformers: Part 1 General requirements |
| IS 3156 PART 2 | Voltage transformers: Part 2 Measuring voltage transformers |

| Standard | Title |
|---|---|
| IS 3156 PART 3 | Voltage Transformers : Part 3 Protective voltage Transformers |
| IS 3156 PART 4 | Voltage Transformers : Part 4 Capacitor voltage Transformers |
| IS 1248 PART 1 | Direct Acting Indicating Analogue Electrical Measuring Instruments and their Accessories - Part: 1 General Requirements |
| IS 1248 PART 2 | Direct Acting Indicating Analogue Electrical Measuring Instruments and their Accessories - Part 2: Ammeters and Voltmeters |
| IS 1248 PART 3 | Direct Acting Indicating Analogue Electrical Measuring Instruments and their Accessories - Part 3: Wattmeter's and Varmeter's |
| IS 1248 PART 4 | Direct Acting Indicating Analogue Electrical Measuring Instruments and Their Accessories - Part 4: Frequency Meters |
| IS 1248 PART 5 | Direct Acting Indicating Analogue Electrical Measuring Instruments and Their Accessories - Part 5: Phase Meters, Power Factor Meters and Synchroscopes |
| IS 1248 PART 6 | Direct Acting Indicating Analogue Electrical Measuring Instruments and their Accessories - Part 6: Ohmmeters (Impedance Meters) and Conductance Meters |
| IS 1248 PART 7 | Direct Acting Indicating Analogue Electrical Measuring Instruments and their Accessories - Part 7: Multi-Function Instruments |
| IS 1248 PART 8 | Direct Acting Indicating Analogue Electrical Measuring Instruments and Their Accessories - Part 8: Accessories |
| IS 1248 PART 9 | Direct Acting Indicating Analogue Electrical Measuring Instruments and Their Accessories - Part 9: Test Methods |
| IS 1651-1991 | Stationary cells and batteries, lead-acid type (with tubular positive plates) |
| IS 13010- | ac Watt hour Meters, Class 0.5, 1 and 2 - Specification |
| IS 13779 | ac Static Watt hour Meters, Class 1 and 2 - Specification |
| IS 8530 | Maximum demand indicators (class 1) |
| IS 14415 | Volt-Ampere hour meters for restricted power factor range - specification [superseding IS:722 (Part 5):1980 |
| IS 14372 | Volt-ampere hour meters for full power factor range [superseding IS:722(Part 7/Sections 1, 2 and 3)-1987] |
| IS 1554 PART 1 | PVC insulated (heavy duty) electric cables: Part 1 For working voltages up to and including 1 100 V |
| IS 1885: Part 32 | Electro technical Vocabulary: Part 32 Electric cables |
| IS 8130 | Conductors for insulated electric cables and flexible cords |
| IS 8130 | Conductors for insulated electric cables and flexible cords |
| IS 2961 | Chrome retains finished upper leather |
| IS 5819 | Recommended Short-circuit Ratings of High Voltage PVC Cables |
| IS 5831 | PVC insulation and sheath of electric cables |

| Standard | Title |
|---|---|
| IS 694 | PVC Insulated cables for working voltages up to and including 1100 V |
| IS 7098 PART 1 | Cross linked polyethylene insulated PVC sheathed cables: Part 1 For working voltage up to and including 1 100 V |
| IS 7098 PART 2 | Cross linked polyethylene insulated PVC sheathed cables: Part 2 For working voltages from 3.3 kV up to and including 33 kV |
| IS/IEC 60947-1 | Low-voltage switchgear and control gear: Part 1 General rules |
| IS/IEC 60947-2 | Low-Voltage Switchgear and Control gear - Part 2 : Circuit Breakers |
| IS/IEC 60898- | Electrical accessories - Circuit-breakers for over current protection for household and similar installations: Part 1 Circuit-breakers for ac operation |
| IS 8828 | |
| IS 2062 | Hot Rolled low, medium and high tensile structural steel |
| IS 1180 PART 1 | Outdoor type three-phase distribution transformers up to and including 100 kVA 11 kV: Part 1 Non-sealed type |
| IS 1180 PART 2 | Outdoor type three-phase distribution transformers up to and including 100 kVA 11 kV: Part 2 Sealed type |
| IS 1370 | Transmission belting - Friction surface rubber belting - Specification |
| IS 13703 PART 1 | LV Fuses for voltages not exceeding 1000 V ac or 1500 V dc: Part 1 General requirements |
| IS 13703 PART 4 | Specification for Low-Voltage Fuses for Voltages not Exceeding 1000 V AC or 1500 V DC - Part 4: Supplementary Requirements for Fuse Links for the Protection of Semiconductor Devices |
| IS/IEC 60947-1 | Low-voltage switchgear and control gear: Part 1 General rules |
| IS/IEC 60947-3 | Low voltage switchgear and control gear: Part 3 Switches, disconnectors, switch-disconnectors and fuse combination units |
| IS 13947 PART 4/SEC 1 | Specification for Low-Voltage Switchgear and Control gear - Part 4: Concessionaires and Motor-Starters - Section 1: Electromechanical Contactors and Motor Starters |
| IS 2086 | Carriers and bases used in rewirable type electric fuses for voltages up to 650V |
| IS 10027 | Composite Units of Air-break Switches and Rewirable Type Fuses for Voltages Not Exceeding 650 V a.c. - Specification |
| IS 12640 PART 1 | Residual Current Operated Circuit - Breakers for Household and Similar Uses: Part 1 Circuit-Breakers Without Integral Over Current Protection (RCCBs) |
| IS 12640 PART 2 | Residual Current Operated Circuit - Breaking for Household and Similar Uses - Part 2 Circuit - Breakers with Integral Over current Protection (RCVOs) |

| Standard | Title |
|---|---|
| IS 2075 | Ready Mixed Paint, Stoving, Red Oxide Zinc Chrome, Priming - Specification |
| IS 8623 PART 1 | Specification for Low-Voltage Switchgear and Control gear Assemblies - Part 1: Requirements for Type-Tested and Partially Type-Tested Assemblies |
| IS 8623 PART 2 | Specification for Low-voltage Switchgear and Control gear Assemblies - Part 2: Particular Requirements for Busbar Trunking Systems (Bus way) |
| IS 8623 PART 3 | Specification for Low-Voltage Switchgear and Control gear Assemblies - Part 3: Particular Requirements for Equipment Where Unskilled Persons have Access for Their Use |
| IS 9920 PART 1 | High Voltage Switches - Part 1: Switches for Rated Voltages Above 1 kV and Less Than 52 Kv |
| IS 9920 PART 3 | Specification for Alternating Current Switches for Voltages Above 1 000 V - Part III: Design and Construction |
| IS 9920 PART 4 | Specification for Alternating Current Switches for Voltages Above 1000 V - Part 4: Type Tests and Routine Tests |
| IS 13947 PART 5/SEC 1 | Low-Voltage Switchgear and Control gear - Specification - Part 5: Control Circuit Devices and Switching Elements - Section 1 : Electromechanical Control Circuit Devices |
| IS 2675 | Enclosed distribution fuse boards and cutouts for voltages not exceeding 1000 V Ac and 1200 V Dc |
| IS 8084 | Interconnecting bus bars for ac voltage above 1 kV up to and including 36 kV |
| IS 5561 | Specification for Electric Power Connectors |
| IS 9921 PART 1 | Specification for Alternating Current Disconnectors (Isolators) and Earthing Switches for Voltages Above 1 000 V - Part I : General and Definitions |
| IS 9921 PART 2 | Alternating current disconnectors (isolators) and earthing switches for voltages above 1000 V: Part 2 Rating |
| IS 9921 PART 3 | Specification for Alternating Current Disconnectors (Isolators) and Earthing Switches for Voltages Above 1000 V - Part III: Design and Construction |
| IS 9921 PART 4 | Specification for Alternating Current Disconnectors (isolators) and Earthing Switches for Voltages Above 1000 V - Part 4: Type Tests and Routine Tests |
| IS 9921 PART 5 | Specification for Alternating Current Disconnectors (Isolators) and Earthing Switches for Voltages Above 1 000 V - Part 5: Information to be Given with Tenders, Enquiries and Orders |

| Standard | Title |
|---|---|
| IS 15086: Part 1 | Surge Arresters - Part 1: Non-Linear Resistor Type Gapped Surge Arresters for a.c. Systems |
| IS 3070 PART 3 | Lightning Arresters for Alternating Current Systems - Specification - Part 3 : Metal Oxide Lightning Arresters Without Gaps |
| IS 9385 PART 1 | High voltage fuses: Part 1 Current limiting fuses |
| IS 9385 PART 2 | High voltage fuses: Part 2 Expulsion and similar fuses |
| IS 9385 PART 3 | High voltage fuses: Part 3 Application guide for high voltage fuses |
| IS 9385 PART 3 | High voltage fuses: Part 4 Determination of short-circuit power factor for testing of high voltage fuses |
| IS 13118 | Specification for High-Voltage Alternating-Current Circuit-Breakers |
| IS 12729 | Common Specification for High-Voltage Switchgear and Control gear Standards |
| IS 8187 | D-type fuses |
| IS 7567 | Automatic circuit reclosers |
| IS/IEC 60947-1 | Low-voltage switchgear and control gear: Part 1 General rules |
| IS/IEC 60947-2 | Low-Voltage Switchgear and Control gear - Part 2 : Circuit Breakers |
| IS 3427 | A.C. Metal Enclosed Switchgear and Control gear for Rated Voltages Above 1 kV and Up to and Including 52 kV |
| IS 3156 PART 1 | Voltage transformers: Part 1 General requirements |
| IS 3156 PART 2 | Voltage transformers: Part 2 Measuring voltage transformers |
| IS 6046 | Specification for Gypsum for Agricultural Use |
| IS 13118 | Specification for High-Voltage Alternating-Current Circuit-Breakers |

c) International Standards

- British Standards
- EN European Standards
- IEC International Electrotechnical Commission
- IEE Institution of Electrical Engineers
- CISPR International Special Committee on Radio Interference CENELEC Comité Européan de Normalisation Elektrotechnique
- ITU-R Comité Consultatif International des Radio communications ITU-T Comité Consultatif International Télégraphique et Téléphonique

d) Unless another standard is specifically mentioned in these specifications, all materials used and provided under the contract and all equipment, calculations and tests shall be in accordance with the standards mentioned before or in accordance with such authorities' standards appropriate to the country of manufacture as in the opinion of the engineer to ensure an equivalent or higher quality.

e) If the Concessionaire offers materials, equipment, calculations, or tests which conform to standards other than the standards mentioned before, full details of differences between the proposed standard and the above-mentioned standards, as far as they affect the design or performance of the equipment, shall be submitted.

f) The Work and all plant, equipment and materials forming part of these specifications shall comply (in all respects) with the rules and regulations of the supply authority and any other authorities having jurisdiction over any part of the work and on the method of performing such work.

### 7.1.11 Tests

a) Tests shall be generally divided into three sections:

I. Factory Acceptance Tests (F.A.T) shall be carried out before the delivery of the plant / equipment

II. Site Acceptance Tests (S.A.T.) shall be carried out after the plant / equipment is delivered and installed on site

III. Tests on completion

b) The Concessionaire shall submit catalogues of all equipment as well as a list of the tests proposed for all equipment. A general overview of each of the proposed tests shall be included in these documents. Any of these pre-given descriptions or documents shall not limit in any way the Concessionaire's obligations to complete every test as specified and necessary to demonstrate the satisfactory performance of the system.

c) The schedules of each test, as well as the test procedures itself shall be prepared, based on the detailed description of the test previously submitted in accordance with the final system proposal and as approved by the engineer. No deviations are allowed without prior approval by the engineer.

d) The Concessionaire shall submit for the engineer's approval all detailed test procedures and final schedules for the tests at least eight weeks prior to the scheduled commencement of the Factory Acceptance Tests.

e) Prior to this time the draft procedures shall be submitted and agreed by the engineer. The Concessionaire shall indicate when these draft procedures shall be submitted.

f) In case of a defect being detected during one of the tests, the nature of the defect shall be explained in detail to the engineer. Based upon this information, the engineer shall decide whether the defect is a minor fault or whether it must be corrected before testing can continue.

g) Minor faults are defects, which are found during testing, and which do not adversely affect the operation of the system in a broad sense and thus don’t need be rectified / corrected before a test can be continued and successfully completed. If the defect is not a minor fault, the engineer shall decide which section of the test (or tests) must be repeated. The engineer shall have the right to require all tests to be repeated, if he decides that the defect has wider consequences.

h) All costs involved in any retesting shall be at the expense of the Concessionaire including supervisory and employer's costs.

i) The engineer or his appointed representative shall always have unrestricted access to the Concessionaire’s and supplier’s premises for purposes of inspection and tests and the Concessionaire shall specify this requirement when placing all orders.

j) All relevant expenses (i.e. transportation, accommodation) of those who supervise the subject’s tests and inspections (engineer and at least one additional representative of the employer) shall be at the expense of the Concessionaire.

k) Factory Acceptance Tests (F.A.T) - Factory Acceptance Tests are divided into three parts:

- Environmental tests
- Technical tests
- System tests

i. Factory acceptance tests shall be conducted under the supervision of the employer and the engineer. The Concessionaire shall group tests to minimize travel expenses if the engineer and / or the employer attends the tests.

ii. After completion of the tests the results, certified by the employer or the engineer's representative, if present in any of such tests, shall be forwarded to the engineer. When the engineer has received the results and states that the plant / equipment has passed the tests, he will write to the Concessionaire to inform him, and the Concessionaire then may ship the plant.

iii. If the engineer deems that the plant / equipment is not in accordance with the specifications, he may reject the plant / equipment and shall inform the Concessionaire of the reasons in a writing within a reasonable time limit.

iv. The engineer shall also inform the Concessionaire in writing if any minor faults are detected and which of these minor faults shall be corrected before shipment.

l) Site Acceptance Tests (S.A.T)

i. If each section of plant is installed, commissioning tests for each section shall be carried out on site.

ii. At least six weeks in advance of any particular site testing, the Concessionaire shall submit details of tests and details for the test equipment he proposes to use for that testing to the engineer for his approval.

iii. As installation proceeds, the insulation resistance of cables shall be checked and recorded. The identification of the cores shall be confirmed from end to end of each cable end, in the case of communication-, alarm- and control-cabling, from end to end of each circuit. Tests on cables shall be completed and accepted by the engineer before the testing of the associated equipment starts.

iv. All tests for statutory requirements and insurances including arrangements for such tests, inspections by authorized bodies, persons or insurers, as necessary and the provision of certificates in the prescribed and approved forms necessary to enable plant and equipment to be put into service, shall be made by the Concessionaire.

v. On-site commissioning tests being subject of acceptance by the engineer shall include:

a. All equipment, cabling, distribution etc. is electrically and mechanically safe

b. All interlocks, isolators and door and cover securing mechanisms shall be properly fitted and adjusted.

c. All the exposed metal work is properly bonded and grounded and that all connections and points required to be grounded for a safe and satisfactory operation shall be properly grounded in accordance with the manufacturer's requirements.

d. All cables, cores and terminations shall be secure, properly fitted and correctly identified and coloured.

e. All phases, polarities, neutral and common connections shall be correctly switched / connected as required, so that the power is correctly available at all points and that the voltage and frequency at all equipment is correct and in accordance with the requirements for correct work

f. All supplies shall be properly fused or otherwise protected, to give successfully discrimination and safe disconnection under fault conditions.

g. All contacts shall be properly aligned / adjusted and not subject to excessive wear or corrosion.

h. Batteries shall be correctly installed, connected and fitted and checked that the battery chargers are working correctly.

i. The insulation-resistance of all cabling and equipment shall not be less than specified.

j. All instruments and meters shall be energized with correct polarity and working properly.

k. All fault indications and alarms shall be working correctly.

l. In addition to all operational tests, required for a successful hand-over, the operation of all interlocks, sequences and protections which are not utilized in normal operations shall be subject of acceptance by the engineer.

vi. The on-site commissioning tests shall be conducted under the supervision of the engineer.

vii. The final acceptance tests shall begin after all on-site commissioning tests have been successfully completed and all defects detected during those tests have been rectified / corrected, which is accepted by the engineer. The tests shall include full operation tests on the works as a whole and selected technical tests on some or all of the equipment.

viii. On completion of the site acceptance tests, the Concessionaire shall forward the test results certified by him to the engineer. When the engineer has received the results and deems that the plant has successfully passed the tests, he will write to the Concessionaire to that effect.

ix. During the site acceptance tests the engineer shall inform the Concessionaire of minor faults detected and which of these minor faults shall be corrected before the beginning of the tests on completion.

**7.1.12** Tests on Completion

1) The Concessionaire shall notify the engineer when the tests on completion shall be made. All minor faults detected during the previous tests shall be corrected to the satisfaction of the engineer prior to the start of the tests on completion.

2) The system shall be fully operational and shall operate successfully. During these periods, the whole system shall be available to the Engineer.

3) Fire Test

a) To get evidence of fully functional and right working tunnel ventilation in case of fire, in the tunnel a hot fire test shall be made.

b) This fire test shall be made during the testing time of the Concessionaire in cooperation with the fire brigade, the employer, and the designer of the tunnel ventilation system.

c) The place(s) of the fire test shall be in agreement with the fire brigade and the employer (the test shall be made at the most unfavorable place for the tunnel ventilation).

d) The aim of the test is to:

i Prove the functionality of tunnel ventilation in case of fire

ii Discover the exhaust capacity of the ventilation system

iii Prove the different driving-programs of the ventilation system in case of fire and adapting / changing these programs, if the fire test results new cognitions.

e) This data shall be acquired:

i Air velocity in the tunnel (value and direction): before and during the test

ii Controlling the tunnel ventilation

iii The rising temperature along the tunnel (in the area of the test)

iv Video recording with the CCTV cameras in the tunnel

v Recording of all alarms and messages during the test

f) Additionally, these data shall be acquired: (therefor necessary equipment shall be included in this item)

i Detection of the spread of the fire and of the layering of the fume with two cameras (in each direction next to the testing place with one camera)

ii Air velocity In each direction, approx. 50 m next to the testing place, the air velocity shall be measured with 3 anemometers; furthermore the air velocity also shall be recorded by a data logger as function over time.

g) The progress, as well as all results of the fire test shall be documented. The protocol shall be handed over to the employer. The video recordings shall be handed over in mpeg-format.

### 7.1.13 Trial Operation

1) The trial operation shall occur with full responsibility of the Concessionaire. The trial operation shall take place after finishing the tests on completion. For starting the trial operation, it is required, that all tests on completion are finished positive for the entire installation and shall occur within 21 days.

2) The trial operation shall show the evidence of a fully functional operation of the tunnel and that security is given during operation. Therefore, the trial operation shall occur without significant malfunctions.

3) The Concessionaire shall test different operation cases during the trial operation (e.g. loss of different equipment etc.).

4) The Concessionaire shall make organizational measurements during the trial operation, so that malfunctions can be rectified as soon as possibly (within max. 2 days).

5) The results of the different tests during trial operation shall be shown in a protocol. This protocol shall be signed by the Concessionaire and the employer. If the protocol shows that all contractual conditions are kept, the tunnel shall be taken over by the employer.

### 7.1.14 Trial Operation

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### 7.1.15 Staff Training

1) During the contract period, the Concessionaire shall provide training manuals, as well as on-site training and training courses to ensure that the employer's staff associated with this project may acquire full knowledge and appreciation / understanding of all aspects of the design, day-to-day operation, breakdown and routine maintenance and fault diagnosis of the power supply, the surveillance and control equipment as well as the belonging hard- and software.

2) The Concessionaire shall train the employer’s personnel about all equipment in theoretical and practical ways. Also the maintenance shall be trained.

3) The employer will nominate members of his staff who are attending the training courses.

4) The Concessionaire shall nominate qualified instructors. It shall be essential that prior approval of the engineer is obtained for the instructor and the instructor's qualifications in each case.

5) The Concessionaire shall provide all relevant and necessary facilities which are needed for complete and effective staff training (such as video, TV, slide- and film projectors and others).

6) The Concessionaire shall provide all facilities including accommodation, transport and catering for all trainees.

7) Within two months after the signing of the contract, the Concessionaire shall submit a detailed syllabus for the training courses for approval by the Engineer.

### 7.1.16 Documentation

1) There will be the following stages for documentation

- Project for execution
- As-built documentation
- Manuals for operation and maintenance

2) Final system manuals and instructions for operation and maintenance respectively compound project of executed works.

### 7.1.17 Project for Execution

(a) The purpose for the final system proposal shall be to form a complete basis on which detailed work can proceed. Without the specific written approval by the engineer, the Concessionaire shall not place any equipment on order or begin with the manufacture of any plant/equipment until the engineer has approved the final system proposal. The final system proposal shall be submitted for the approval of the Engineer.

(b) This final system proposal phase shall include specifications of:

- All low-voltage power supply
- all emergency power supplies
- All earthing and potential equalization
- All the lighting

- All tunnel fittings
- All ventilation equipment
- All fire detection systems
- All SCADA system
- Acceptance testing
- Documentation of organization
- Data and communication equipment

(c) Software Final System Proposal

(1) The final software system proposal shall contain flow charts and descriptions of the whole software structure explaining the operation and interaction of the various programs. All operation functions and interfaces to be provided in each central and local system(s) shall be specified. The interfaces between single programs and data structures shall be designed. Critical timings shall be evaluated and displayed.

(2) The document shall concentrate on producing and describing adequate overall system design with unified systems of data modification, etc.

(3) If standard programs are used, detailed documentation for each program shall be provided. This shall include a functional description of the program(s), with flow charts, table structures, interfaces, definitions, timings, storage, and the source listings etc.

(4) For off-the-shelf software packages, which shall be part of the completed application software, the off-the-shelf software package's detailed documentation shall be supplied.

(5) Control software shall support the operator with online help.

(d) Hardware Final System Proposal

(1) The hardware final system proposal shall be written in conjunction with the standard items for the component processor and associated peripherals. If any of the hardware shall be designed or modified for this specification, the specified technical details shall be defined. The proposal shall include a detailed description of the processor system, the method of connection of the peripherals and the transfer of information, including the data transmission system. A full breakdown of the equipment shall be prevented with physical layout, interconnections, and power supply arrangements.

### 7.1.18 Acceptance Testing

1) All test specifications and schedules for acceptance tests to be performed at the various stages shall be finalized during the final system proposal stage. These shall form the basis on which detailed test procedures can be written.

2) Hardware tests: All hardware test schedules shall be defined. This definition shall include reviews and modifications from the Concessionaire's standard factory tests if required. A review of the standard diagnostics shall be undertaken.

3) Software and system tests: This shall include all acceptance tests to be performed on the individual programs and the complete system. Detailed test specifications, schedules for all tests described elsewhere in these specifications and any other tests as necessary for demonstration of the performance, correct operation of the system, etc. shall be provided. The sequence of tests and the grouping of equipment for each test shall also be defined.

### 7.1.19 Manuals for Operation and Maintenance

1) To maintain the liaison between the Concessionaire's organization and the engineer, documentation concerning each part of the specifications shall be produced as part of each component job / work, in such a form which can be issued immediately.

2) The Concessionaire propose a modular system for the build-up of this information.

3) Sections issued during the contract shall be regarded as a draft form, as subsequent jobs shall inevitably interact and require modification, documentation is vital even if several re-issues are necessary.

4) The Concessionaire's proposal shall include provision for resources to produce the documentation throughout the contract.

5) Effort shall be given on recording and familiarity with the presentation of information maintained, by writing documentation issued during the contract in a form suitable for inclusion in the relevant final manuals.

6) A copied set of the standard proprietary documentation of all the equipment supplied under this contract shall be provided within the first five months of the contract. It will be acceptable if such standard documentation is submitted as part of the documentation forming the final system proposal. But finally, a number of at least 5 copied sets shall be handed over to the employer.

### 7.1.20 Final Documentation – System Manuals

1) The final documentation shall consist of the following parts:

- Software manual
- Programming manual
- Hardware, maintenance and servicing manuals, including all equipment
- Tunnel Operator's Manual

2) Where appropriate, standard documentation and project documentation submitted during the contract shall be included in the final system manuals.

3) Not less than six weeks before the commencement of the site acceptance tests, three draft issues of the final system manuals shall be submitted to the engineer for information and approval. This draft issue shall have the same number of parts and format as the final system manual. Re- issues shall be provided if site commissioning and tests make this necessary.

4) When approved, one copy of the draft documentation, amended as required, shall be returned to the Concessionaire.

5) Six complete sets of the final system manuals together with six copies of complete subject index shall be supplied before the issue of the taking over certificate (acceptance certificate).

### 7.1.21 Software Manual

1) The software manual shall be project oriented.

2) The software manual shall include the system's programs and the system's data records. Standard detailed programming assistance shall be left to the programming manual.

3) The information shall follow the specification of the final system proposals.

4) The manual shall explain the overall software structure with flow charts and descriptions, with particular attention to the points at which further user programs can be interfaced. It shall be essential that the complete operating structure is explained in such a way that it may be clearly understood, especially by any competent programmer who wishes to specify or interface a new program into the system. Each program shall have a general description with a related flow chart.

5) In the overall description, the allocation of the addressable storage of the component's jobs shall be listed, with limits of spare capacity. A detailed description of each component's job in the operating system shall follow, including the executive-, handler- and user-programs (the newest version and inclusive updates).

6) The format of all data structures shall be described as a second part to the manual. The data records of diagram formats, variables etc., shall be listed in a form compatible with the data updating system.

7) Source listings for all software supplied, including standard and application program libraries, form part of this manual, except for off-the-shelf software packages for which only a right of use can be purchased.

### 7.1.22 Hardware, Maintenance and Servicing Manual

1) The manual shall contain a description of the complete hardware system followed by maintenance procedures. The maintenance procedure for tunnels shall contain that in case of maintenance or accidence, the tunnel management shall be done manually by the maintenance people at the Control Centre. For standard equipment, proprietary documentation shall be included.

2) The hardware description shall start with the overall configuration of the system, with layouts showing the location of every unit, with block diagrams and explanation of the operation.

3) Detailed descriptions of component units shall explain their operation. Block diagrams (showing the flow and interaction of data), logic diagrams, circuit diagrams (with component values) and layout diagrams including cabling diagrams (showing the interconnection between equipment) shall be provided. Part- and cable-lists shall be provided, but care shall be taken to avoid these obscuring the operational description. Maintenance procedures shall cover the diagnosis of faults, testing and set-up adjustments, replacement of units, routine mechanical servicing and operation of test equipment.

4) The use of test programs shall be explained with step-by-step instructions. The detailed listing of the programs itself shall be provided separately.

5) Step-by-step description for the replacement of plug-in units of the computer system shall be given, with set-up values and checking of power supply voltages etc. where appropriate. Routine mechanical service shall be covered.

6) Sections on the following equipment shall be bound in separate volumes, as indicated below, for easier use by the maintenance personnel:

- All Low-Voltage Power Supply
- All Lighting
- All Ventilation Equipment
- All Air Control System and Ventilation Control System
- All Fire Detection System
- All SCADA System
- All Room Ventilation and Climate Conditioning
- Control Centre

### 7.1.23 Tunnel Operator's Manual

1) This manual shall be written specially for use by the tunnel operators at the Control Centre. It shall consist of specific sets of procedures and instructions necessary for effective operation of the system.

2) The manual for the Control Centre shall include:

a) Step by step instruction for fault conditions, fire alarm and all other alarm conditions

b) Step by step instructions on the use of all console equipment. The manual shall be suitable for continuous usage.

### 7.1.24 Presentation of Documentation

1) All documentation shall be in English language.

2) All documentation shall carry a unique issue number and date.

3) All documentation shall be indexed, with a complete subject index in the final issue.

4) All documentation shall be produced in a uniform format in compliance with the employer's requirements. All diagrams relating to the final documentation shall be reduced to page height, bound and correctly referenced to the text.

5) The final documentation shall be delivered in durable hard cover-bindings. The bindings shall be in a loose-leaf form (ring-binders) and permit easy interchange or replacement of pages. Each ring binder shall be identified by an easily readable title / attached to both, the front face and the spine of the ring-binder.

6) Seven copies of each document shall be provided.

### 7.1.25 Concessionaire's Drawings

1) The Concessionaire shall submit drawings in such a form as the engineer will require them for approval, copies as required of all drawings, diagrams and details of all equipment in part or in whole. The Concessionaire shall make any drawings available to the engineer at all reasonable times. Wiring diagrams and other drawings as the engineer deems shall not be finally settled until satisfactory installation and testing has been made, this shall be approved in principle.

2) The Concessionaire shall submit a schematic block diagram of the equipment showing the manner, in which the functional requirements of this specification shall work together.

3) Before the Concessionaire begins installing of his parts of the contracts, the Concessionaire himself shall check all civil works ensuring all equipment can be installed.

4) Within one month after the signing of the contract, the Concessionaire shall submit a schedule including details of numbering, categories and drawing registers / indexes for the production, submission and approval during the period of the contract of drawings and also of any information required for the engineer in connection with the design of the contract works.

5) This schedule shall be suited to the requirements of manufacture, delivery and installation of the contract works to meet the requirements of the contract and shall allow reasonable time (approx. 8 weeks) for study and approval by the engineer of all drawings, calculations and graphics submitted (and as necessary, resubmitted) by the Concessionaire.

6) No approval by the engineer of any drawing shall relieve the Concessionaire of any of his obligations of liabilities under the contract or of his responsibility for ensuring that the work is satisfactory done and that all operational requirements shall be met.

7) The Concessionaire shall provide drawings without undue delay, and in any case within twelve weeks of the award of the contract, these drawings shall include dimensions of equipment to be located in equipment rooms and details of cable routes and recesses / outlets, entry of equipment to cabinets, etc.

**7.1.26** As -Built Drawings

1) Preparation of the as-built drawings shall be part of these specifications. As-built drawings will be revised final design drawings of the project showing the actual work done.

2) The Concessionaire shall provide the as-built drawings in one original and one reproducible negative produced from the original, with the names of the signature authorities of the employer, the engineer and the Concessionaire. After they are signed for approval, five prints shall be taken from the signed original of each drawing. Also DVDs with all as-built drawings shall be handed to the employer.

3) Together with the as-built drawings, the Concessionaire shall provide six sets of reduced size (e.g. A3 size) booklets of the as-built drawings. All details, dimensions, texts, etc., on the reduced size drawings shall be clearly recognizable and readable.

4) The Concessionaire shall complete and obtain the engineer's approval on the as-built drawings and make the final submission of the as-built drawings together with the A3 size booklets latest within three months following the date of the Certificate of Completion.

5) All costs associated with the provisions mentioned above shall be deemed to be included in the contract price.

6) As-built drawings shall cover in general:

a) For mechanical equipment:

i. Construction drawings,

ii. Instruction drawings,

iii. Functional block diagrams

b) For electrical installation:

i. Installation drawings with circuit numbers and exact type-assignation of all installed equipment,

ii. Distribution diagrams with circuit numbers,

iii. Fault analysis and protection co-ordination settings the of protection system,

iv. Power consumption,

v. Precise type numbering

vi. Earthing systems

c) For distribution cabinets:

i. Construction drawings,

ii. Circuit drawings as operating diagrams,

iii. Additional current flow-charts where required,

iv. Accurate lists of any installed equipment with precise description of this equipment,

v. Adjustment tolerances of circuit-breakers, switches, etc.

d) For equipment:

i. Construction drawings,

ii. Circuit diagrams,

iii. Functional block diagrams,

iv. List of quantities

e) For cabling:

i. Diagrams with dimensions, type of cables and power requirements with regular cross- section area and measured cable values shall be used for these diagrams.

## 7.2 Technical specifications

### 7.2.1 33 KV SYSTEM

#### 1. General

a) 33 KV GIS substations shall be constructed at the tunnel portal by client. 33 KV cables will terminate at 33 / 11 KV grid substation. The 33kV switchgears assembly having CTs, PTs, Isolators, and circuit breakers shall be kept indoors.

b) The assembly shall have the following configuration:

- 2 nos. incomers for 33 KV cables from SEB
- 1 no Bus coupler
- 2 nos. outgoings for 33/11 KV transformers

c) 33 KV switchgear panel shall be 3 phase combined & single bus type. CT ratio shall be X/1 amp and PT shall be 33000/√3 Volt / 110/√3 Volt. All the panels shall be operated and monitored through SCADA. Substation shall be capable to be controlled locally as well as from remote.

d) 33 KV panels shall be controlled by 24-volt DC, by lead acid battery. The batteries shall be charged with an independent charger.

e) There is one no. 33/ 11 kV grid substation at each portal end of North-south corridor.

#### 2. Scope of work

a) The high voltage supply system shall include the delivery, installation, required works, tests and all necessary equipment for the following materials:

- 33 kV Switchgear (panels / cubicles)
- 33 kV cables
- Protection System
- Transformers
- Accessories
- Potential equalization connection
- Wiring – Signalling for 33Kv

#### 3. Technical Specification -33kv Gas Insulated Switchgear

a) The insulated, medium voltage switch gears shall be designed to equip indoor HV/MV, MV/MV or MV/LV Substations. The switchgear shall meet the criteria for indoor metal enclosed metallic partitioning, LSC2 accessibility GIS switchgear and control-gear for rated voltages above 1kV and up to and including 52kV, in compliance with the

IEC 62271-200. In principle, the arrangement shall follow the latest modern engineering practice, to ensure optimum continuity and reliability of supply, as well as the safety of the operating staff. Design shall consider minimum space requirements, no maintenance in medium voltage part and minimized maintenance in the mechanisms. The switchgear shall be of modular design and minimized dimension gas insulated type (SF6).

b) The switchgear shall be designed for continuous operation under all system operating conditions including sudden change of load and voltage and short circuits within its ratings. The equipment shall be designed to withstand normal operating voltage even if the isolating gas pressure decreases to atmospheric pressure. All switchgears and material provided with them shall be the standard products of the manufacturer, which are regularly designed, manufactured, tested and serviced for at least 15 years.

**4. System Parameters**

| | |
|---|---|
| Rated Voltage (System Highest Voltage) | 36kV |
| Rated Power frequency withstand voltage | 70kV |
| Rated lightning impulse withstand voltage | 170kV |
| Frequency | 50Hz |
| No. of phases | 3 |
| System fault current (Sym.) | 25 KA for 3 sec. |

**5. SERVICE CONDITIONS:**

a) Switchgear shall meet the operating conditions, for indoor applications, according to the IEC 62271-1 standard where the environment:

- .....Minimum temperature: : 15ºC
- .....Maximum temperature: : 35ºC
- .....Altitude: : up to 900 m
- .....Maximum relative humidity : 55 to 85%

**6. Compartment Arrangement, Functional Units**

a) The switchgear shall be single busbar system. Each cubicle shall have the next compartments:

b) General Busbar compartment - tool accessible – touch proof solid insulated System (screened and earthed) containing:

- .....Main busbar, segregated phases
- .....Bus Mounted CT-s if applicable
- .....Bus Mounted VT-s if applicable
- .....Three position Disconnector (Closed-Open-Ready to earth)

c) CB compartment - non withdrawable and accessible - SF6 Gas Insulated Containing:

- .....Vacuum Circuit Breaker
- .....Three position Disconnector (Closed-Open-Ready to earth)
- .....MV Cable connection bushings

d) MV cable compartment - interlock accessible - in Air

- .....MV cables connection points
- .....Cable Side CT-s if applicable

- .....Line VTs as per as per IEC 62271-200- if applicable

**7. MV Compartment**

a) The switchgear shall be modular type. The Loss of Service Continuity class (LSC) shall be 2A (LSC2A) for all functional units. Gas insulated compartments must be segregated in each cubicle and from cubicle to cubicle by means of gas tight barriers. The busbar shall be insulated with single phase solid insulation, shielded and earthed through the entire switchboard making impossible any phase-to-phase fault and having the same advantages as the Gas insulated Busbars systems.

b) The general degree of protection must be IP-65 for all MV parts. All the cubicles must be factory filled and tested to assure a gas leakage of less than 0.1% per year, sealed FOR LIFE pressure system and guarantee no gas handling at a site during extension, removal and installation at site. SF6 gas used for insulation must comply with IEC 60376 / IS-13072-2013 and IEC 60480. The design of the switchgear shall be such as to enable extensions to be added at either right or left side, with the minimum of disturbance to the installed equipment. Every current-carrying part of the switchgear including Disconnector, Busbars, Connections and joints shall be capable of carrying its specified rated normal current continuously and in no part shall the temperature rise exceed the values specified in relevant IEC Standards.

c) Every part of the switchgear shall also withstand without mechanical or thermal damage the instantaneous peak currents and rated short-time currents pertaining to the rated breaking capacity of the switchgear.

**8. Functional Type Requirement**

a) Each functional unit shall contain all the elements needed to perform its function. Each functional unit shall be identified by a label which clearly indicates its functional and electrical characteristics.

b) The functional units shall be the following:

- .....Incoming / Outgoing feeder function.
- .....Bus-tie function (consisting of bus coupler and bus riser cubicles).
- .....Load Break Switch Disconnector cubicle.
- .....Busbar VT-s and CT-s will not need any specific cubicle and must be capable of being connected directly to the general busbar system.
- .....Load Break Switch Disconnector with associated fuses.

**9. Construction/Architecture**

c) Busbar Compartment

- .....Placed on the top part, inside the SF6 compartment.
- .....Containing main copper busbar system
- Containing also the 3 position Disconnector.
- .....Disconnector operating mechanism must be placed out of the SF6 gas atmosphere.

d) Circuit Breaker Compartment

- .....SF6 insulated compartment containing gas tight barriers.
- .....Containing also the 3 position Disconnector.
- .....Disconnector operating mechanism must be placed in the front of the switchgear and out of the SF6 gas atmosphere. Rear operation not acceptable.
- .....Containing Vacuum breaking technology CB.
- .....Placed on the middle side of the cubicle.
- .....CB operating mechanism must be placed in the front of the switchgear and out of the SF6 gas atmosphere. Rear operation is not acceptable.
- .....Low voltage cables going through MV compartments are not acceptable.

e) Cables Connection

There is one type of cables connection for GIS switchgears:

- .....Outer cone bushings.
- .....Threaded connection. "C" type bushings according to EN 50181, IS2099, IS10314, IS-5621, IEC-60137 standard.

f) Cables Compartment

- .....Placed in the bottom rear part of the cubicle. Front access is a must with enough room for cable connection, rear access is not acceptable.
- .....Containing Connection points for the above-mentioned cable connectors (refer to "CB compartment")
- .....Optionally it might contain ring type current transformers
- .....Optionally it might contain VT-s connected to the above-mentioned outer cone type bushings.
- .....Containing also cable clamps and the earth connection for the cubicle enclosure.
- .....All MV components inside this compartment shall be insulated, shielded and this shield connected to earth.

## 10. LV Compartment

a) Placed in the top front part of the cubicle, front access complete front access to all elements permits the installation of the cubicles close to the rear wall. Each cubicle shall have four levelling bolts in order to provide accurate levelling during assembly. The switchgear shall be constructed of suitable material and thickness to withstand the mechanical and thermal stresses due to short circuits. For the rated duration of short circuit, reference shall be made to the design fundamentals and latest IEC recommendations.

b) Switchgear has to be internal arc withstand classified and the performance shall be as a minimum, IAC AFLR 25 kA as described in the IEC 62271–200 standard. The tanks containing all MV components and filled with SF6 gas shall be made stainless steel of least 2.5mm thick. All the accessible enclosure parts must be conveniently earthed to avoid any risk. All front and lateral panels shall be painted in textured RAL 9002. Rupture flaps shall be provided in main compartment to allow for pressure relief in a non-probable case of overpressure. Each switchgear bay shall be earthed through an appropriate copper earth bar, which is to run also along the full length of the switchgear with a minimum section of 200$mm^2$.

c) Numerical relay shall be of modular type and have native IEC 61850 communication support for RTU/SCADA integration. Relay shall be with graphical LCD dot matrix display with single line diagram mimic with control, indication, programmable function key and LEDs.

d) Numerical Relay shall have minimum following protections 50/51, 50N/51N, 46, 86, 50ARC, 50NARC as native function. Arc Flash protection shall be integral part of relay. Protection relay hardware, cables and separate arc sensors shall be included. Any arc flash fault in the cable compartment is selectively cleared by the feeder protection relay.

e) Numerical relay should be with G3 conformal coating and suitable to work in Industrial corrosive environment and should have passed mixed gas test as per IEC 60068-2-60:1995, Part 2, Test, Method (Class 3). The test to include 21 days at 75% relative humidity or 5 days at 90% relative humidity and +30 deg C, exposure to elevated concentrations of $H^2S$, $NO_2$ and $CI_2$.

## 11. Components

a) Circuit Breaker - Circuit breakers should be Vacuum type. They should be according to IEC 62271-100 standard. Rated operating sequence must be O-0.3Sec-CO-3Min-CO. Operating time for opening, breaking and closing, less than 100ms. Circuit breaker must be E2/M2/C2 type (electrical, mechanical endurance and capacitor breaking/making ability) according to relevant standard. Circuit breaker operating mechanism will be outside the SF6 tank, manually and electrically operated. Vacuum Interrupter shall be tested for min. 100 nos. of full short circuit operations at rated fault level. Vacuum interrupter must be GIS manufacturer's own make and should be type tested design. The operating mechanism should consist in the following items.

- .....Spring system that stores the necessary energy for opening and closing operation.
- .....Spring charging system (motor operated) that automatically recharges the springs after the main contacts of the CB have closed.
- .....Mechanical "charged-discharged" position indicator for CB opening and closing springs.

- .....Manually operated spring charging system (in case of lack of auxiliary power supply).
- .....Electrical system including:
  - .....Closing coil
  - .....Tripping coil
  - .....Anti-pumping relay
- .....Mechanical emergency trip pushbutton.
- .....Operation counter
- .....Spring charging indication contact.
- .....Mechanical indicator for Open / Closed position
- .....Minimum CB position auxiliary contacts

b) Disconnector

i. The Disconnector is a mechanical device which provides, in the open position, an isolating distance. The Disconnector is always operated with NO LOAD (zero current). The Disconnector will be placed between the CB and the busbar system in order to isolate the busbar system from the circuit side and earth the CB busbar terminals. The Disconnector shall be of three position types, Closed-Open-Ready to earth, in order to avoid the needs of interlocks between the busbar Disconnector and Earthing switch. Separated elements are not acceptable. The Earthing Disconnector will operate always de-energized and the making capacity is provided by the circuit-breaker, which is designed for these purposes.

ii. The Disconnector must be according to the latest edition of the IEC 62271-102 and shall meet requirements as specified RATINGS. The indication of the position of the Disconnector must be mechanical. This mechanical link must be kinematic chain tested. The Operating mechanism must be outside the SF6 atmosphere and accessible from the front.

iii. As the Disconnector is not for operating purposes, the local manual operation by the operator is advisable against the remote-electrical one. Therefore, only manual operation is necessary. The Disconnector must be of single rotation-driving axis both for the Disconnector and the Earthing switch. It is mandatory that the operation from "closed to busbar" to "ready to earth" is made in two separate operations, closed - open and open - ready to earth. These are completely independent operations, with two separated operating access.

c) Busbar - Busbar shall be single phase or three phase SF6 gas encapsulated through the whole switchboard, in order to:

- .....Maintain the advantages of SF6 insulation not affected by ambient condition.
- .....Reduce the possibility of a fault due to external cause
- .....Reduce the dimensions

d) Voltage Transformers

i. Voltage transformers shall be completely touch-proof type suitable for mounting at the cable connection or on the busbar, outside the gas compartment

ii. Instrument transformers shall be suitable for continuous operation at the ambient temperature prevailing inside the switchgear enclosure, when the switchboard is operating at its rated load and the outside ambient temperature is 45 deg. C.

iii. Feeder voltage transformers must be disconnect-able to **ON-OFF switch inside Gas tank to** perform cable tests without having to remove the transformers.

iv. Busbar voltage transformers must be designed to withstand 80% of the power-frequency withstand test voltage to enable repeat tests at the busbar without having to remove the transformers.

v. Current/voltage sensors, Rogowski coil and or other non-standard arrangements are not acceptable.

vi. <u>Common characteristics for all transformers:</u>

- .....Permanent over voltage = 1.2xUn

- .....Voltage factor = 1.9 x Un/8 hours - 2.5Un peaks.

vii. The following types and mounting possibilities will be accepted:

VT-s for Busbar Voltage metering

| Location | Mounting |
|---|---|
| In Busbar Compartment | Directly connected to the Busbar system (Plug type connection) Over the Busbar. To place 3VT's is needed the wide of two switchgears. |

VT-s for Line Voltage metering

| Location | Mounting |
|---|---|
| In MV cables Compartment | Inside the enclosure of the switchgear Connection by a solid isolated plug-in type cable with plug in connectors in both ends. |

e) Current Transformer

i. CTs must be ring type and manufactured according to IEC 61869-1, IEC 61869-2 and IS-16227 standards. Transformer's burdens and accuracy classes will be according to the relay characteristics and the protection system characteristics. In accordance with the requirements of currently available relays, the CT-s will be, preferably, with one secondary connection which includes protection and measurement in the same connection. Due to the low power requirements of the digital relays and the closeness between CT and relay, these ones will feature the minimum power output necessary for the protection system. Sensors in place of conventional CT / VT are not acceptable.

f) OPERATION AND INTERLOCKS

i. Common operations in a substation must be available combining different functional units, such as:

- .....Connect line to busbar.
- .....Isolate line from busbar.
- .....Earth the line.
- .....Couple right busbar section to left busbar section (through bus tie).
- .....Isolate right busbar section from left busbar section (through bus tie).
- .....Earth right section of busbar (through bus tie).
- .....Earth left section of busbar (through bus tie).

ii. The interlock system shall prevent any incorrect operation of the circuit breaker, switches and Disconnector. Mechanical and electromechanical interlocks are preferred over other type of interlocks. There shall be interlocks related to the switchgear itself and also related to all the switchgears in the substation, in order to maintain safety in all operations.

- .....**INTERLOCKS RELATED TO THE SWITCHGEAR ITSELF:**
- .....**DISCONNECTOR**

- .....Operating handle of the Disconnector can only be removed or inserted once the operation has been completely finished.
- .....It is not possible to go from "close" position (Disconnector connected to busbar) to "ready to earth" position (Disconnector connected to earth system) in one opera tion.

g) DISCONNECTOR & CIRCUIT BREAKER

i. Disconnector only to be operated with the Circuit breaker in open position.

- .....Circuit breaker to be maintained in open position while Disconnector is being operated or operating handle is in inserted position.

h) EARTHING THE CIRCUIT

i. A copper / aluminium earth bus of suitable size shall be provided at the bottom extending through the entire length of switchgear. Each stationary unit of the cubicle shall be earthed directly to the earth bus through a contact bar so that the carriage is earthed at all times except when the primary disconnects are separated by a safe distance. Suitable clamp type connectors shall be provided at both ends of earth bus to suit external earthing conductor. Also hinged doors of the cubicle base plate of C/T and P/T shall be effectively earthed. Earth bus shall protrude outside the extreme end panels and by at least by 100 mm.

ii. One set of earthing accessories shall be supplied with the switchgear for earthing of the outgoing side of a feeder or 3 phase bus bars of the switchgear either through earthing facility which comprises truck to be inserted in place of circuit breakers, separate earthing trucks shall be supplied where earthing is achieved through circuit the earth device unless the circuit breaker is in open and isolated position.

- .....Line earthed position (Disconnector in earth position and Circuit breaker closed) can never be electrically removed. Circuit breakers can only be opened by means of a mechanical push button.
- .....Line earthed position must have a key lock to assure earth position in all moments.
- .....Access to the cable compartment will only be possible when the circuit is in an earthed position.

i) ACCESS TO MV CABLE COMPARTMENT

- .....It will be impossible to access the MV cable compartment unless the cables are conveniently earthed.

**Table 1: TECHNICAL DATASHEET – 33kV GAS INSULATED SWITCHGEAR**

| **Sl. No** | **Description** | **Technical Parameters** |
|---|---|---|
| 1 | Switchboard | |
| 2 | Manufacturer's Name | By Bidder |
| 3 | Type | By Bidder |
| 4 | Standards Followed | IEC 62271-100/200 |
| 5 | Main Bus bar | |
| | a) Current Rating | 630A |
| | b) Material | CU |
| | c) Grade | Electrolytic Cu |
| | d) Whether Joints are Silver Plated | N.A |
| | e) Thickness of Coating | N.A |
| 6 | Earth Bus bar | |
| | a) Current Rating | 25kA |
| | b) Material | CU |
| | c) Grade | Electrolytic Cu |
| | d) Whether Joints are Silver Plated | N.A |

| | | |
|---|---|---|
| | e) Thickness of Coating | N.A |
| 7 | Continuous current Rating for Ambient Condition of site when installed in IP 4X Switch board | |
| | a) Main Bus bar at Ambient Specified | 630A |
| | b) Tappings at Ambient Specified | 630A |
| 8 | Temperature rise of Bus bars while | |
| | a) Carrying rated Current and Installed in IP4X enclosure at an Ambient Temp specified. | As per IEC-60694 Table-V, IS-12729-2004 |
| | b) Under Short Circuit Condition | N.A |
| | Degree of Protection of Enclosure | SF6 gas chamber- Stainless Steel IP65<br>Drive-IP2X<br>Low Voltage-IP3X |
| 9 | Minimum Clearance in Air | |
| | a) Between Phases | Since all parts in SF6, clearance is not applicable. |
| | b) Between Phase to Earth | Since all parts in SF6, clearance is not applicable. |
| 10 | Clearance required at the Back & Front of Panel | AFLR: 800 mm @ rear<br>1700 mm @ front |
| 11 | Overall Dimension of the Switch Board (mm) | |
| | a) Length | In line with Switch Board Configuration |
| | b) Width | By bidder |
| | c) Depth | By bidder |
| | d) Height | By bidder |
| 12 | a) Access Height (mm) | |
| | i) Maximum | By bidder |
| | ii) Minimum | By bidder |
| | b) Weight of Panel Board (kg) | |
| | j) Maximum : | By bidder |
| | k) Minimum : | By bidder |
| 13 | Insulation Level including all the Components | |

| | | |
|---|---|---|
| | a) Power frequency withstand Voltage for 1 min | 70 kV |
| | b) 1.2/50 μ sec Impulse Withstand Level | 170 kV |
| 14 | Circuit Breakers | |
| (i) | Manufacturer's Name | |
| (ii) | Type | |
| (iii) | Manufacturer's Type reference | |
| (iv) | Closing Mechanism | spring |
| (v) | Normal Current rating in Air & corresponding | 630A |
| (vi) | Ambient Temperature | 40°C |
| (vii) | Derating factor for Ambient condition at Site | N.A |
| (viii) | Service Voltage & Frequency | 33 kV, 50 Hz |
| (ix) | Maximum Voltage at which CB can Operate continuously | 36 kV |
| (x) | Rated Making Capacity | 25kA |
| (xi) | Rated Breaking Capacity | 78kAp |
| (xii) | a) Symmetrical | 25kA |
| (xiii) | b) Asymmetrical | |
| (xiv) | Short Circuit With stand Capacity | |
| | a) 3 Sec | 25kA |
| | b) 1 Sec | 25kA |
| (xv) | Total Make time | Within 80ms |
| (xvi) | Total Break time | Within 60ms |
| (xvii) | No. of Breaks per pole | 1 No. |
| (xviii) | Total Length of Break per pole | |
| (xix) | No. of Auxiliary Contacts (NO/NC) for Employer's use | 8 |
| (xx) | Type of Arc Control Device | Vacuum |
| (xxi) | Arc Duration time | |
| | a) 100 % Load Current | Within 10ms |
| | b) 10 % Load Current | Within 10ms |
| (xxii) | Spring Charging Motor | |

| | | |
|---|---|---|
| | a) Type | Universal Motor |
| | b) Voltage | 230 V AC |
| | c) Rating in kW | By bidder |
| | d) Protection relay provided | Not Applicable |
| | e) Protective MCB s provided | Yes |
| (xxiii) | Power required for : | |
| | a) Closing | |
| | i) Momentary | 250W |
| | b) Holding | N.A |
| | c) Tripping | 250W |
| | d) Time taken for Charging Motor to Charge Spring completely | 15 seconds |
| (xxiv) | Number of consecutive operation the breaker can withstand and the recommended interval between these operations: | O-0.3Sec-CO-3Min-CO |
| (xxv) | Number of short circuit current interruption after which the breaker requires attention & maintenance | 100 @ 25 kA STC |
| (xxvi) | Number of normal operations after which the breaker requires attention & Maintenance | 10000 |
| (xxvii) | Rated capacitor breaking current of breaker/ contactor of each rating | N.A |
| (xxviii) | Confirm that trip and closing coils will be suitable for 110 V DC and the spring charging motor will be suitable for 240 V AC | Yes |
| (xix) | Maximum number of XLPE cables & sizes that can be terminated safely in the cable chamber without extension panel | |
| | a) Single core (Size & No. of Runs) | N.A |
| | b) Three core (Size & No. of Runs) | Max. 1 cable XLPE<br>Three core 400 sq.mm |
| (xx) | Maximum no of cables that can be terminated in the cable extension box (Please state the dimensions of such cable extension Box) | N.A |
| (xxi) | Minimum available distance from the bottom of the panel to the terminals in cable box/chamber for terminating cables | By bidder |
| (xxii) | Weight of circuit breaker and truck | fixed mounted GIS |
| 15 | **Instrument Transformers** | |
| (i) | Makes | |
| | a) CTs | By Bidder |

| | | |
|---|---|---|
| | b) PTs | By Bidder |
| (ii) | Standards followed | IEC / IS |
| (iii) | Confirm that CTs and PTs will be epoxy resin cast insulated | CT foil, VT metal-cast resin |
| (iv) | 3 second short time current rating of CTs, kA. | 25kA |
| (v) | 1 second short time current rating of CTs, kA. : | 25kA |
| (vi) | Dynamic current rating of CTs, kA : | 78kAp |
| (vii) | Confirm that accuracy classes shall be as specified and ratios and capacities shall be as required | Yes/No |
| (viii) | Confirm that all protective, metering, control and annunciation devices, transducers as specified shall be provided | Yes/No |
| (ix) | Enclose technical particulars, data sheets, catalogues of all types of relays and other plant being offered by you | Yes/No |
| 16 | IP Rating | |
| | (a) Tank | IP 65 HV part |
| | (b) Cubicle assembly | IP 3X |
| 17 | SF6 Gas Pressure | As per bidder's type tested design |
| 18 | Gas Leakage Rate | < 0,1% per year |
| 19 | Gas handling Requirement at Site | No Gas handling allowed at site |
| 20 | **Cable Terminations** | |
| | Make | By Bidder |
| | Type | Outer Cone screen separable connector |

**TABLE 2: TECHNICAL DATASHEET FOR CURRENT TRANSFORMER**

| **Sl. No.** | **Particulars** | **33 kV CT Unit** |
|---|---|---|
| 1 | Nominal System Voltage (KV RMS) | 33 **or 0.66KV incase LV CT used** |
| 2 | Highest System Voltage (KV RMS) | 36 **or 0.72KV incase LV CT used** |
| 3 | Frequency | 50 Hz |
| 4 | Rated Output (V.A. burden) | **As per suitable VA calculation** |

| | | |
|---|---|---|
| 5 | Rated continuous thermal current | 1.2 times of rated primary current |
| 6 | Short time current rating for 1 sec | 25 kA for 1.0 seconds |
| 7 | Rated dynamic current (peak) | 2.5 times of short time thermal current |
| 8 | Instrument security factor | Less than 5 (five) |
| 9 | Impulse withstand voltage (kV peak) (on CT) | 170 **or not applicable for LT CT used** |
| 10 | Maximum temperature raise over max. ambient temperature of 45°C at rated continuous thermal current at rated frequency and with rated burden | As per IS 2705 / 1992 (part-II) |
| 11 | Maximum ratio error | Do |
| 12 | Maximum phase angle error | Do |
| a | Type | Dry type epoxy resin cast |
| b | No. of cores | One |
| c | Rated continuous thermal current | As per IS 2705 / 192 |
| d | One minute power frequency voltage withstand test on secondary winding | 3 kV |
| e | Class of accuracy | **0.5S or as per approved SLD** |
| f | Secondary termination | S1 & S2 shall be clearly engraved |
| g | Primary termination | P1 & P2 shall be clearly engraved |

**TABLE 3: TECHNICAL DATASHEET FOR POTENTIAL TRANSFORMER**

| **Sl. No.** | **Particulars** | **33 kV PT Unit** |
|---|---|---|
| 1 | Nominal System Voltage (KV RMS) | 33 |
| 2 | Highest System Voltage (KV RMS) | 36 |
| 3 | No. of phases | 3 |
| 4 | Frequency | 50 Hz |
| 5 | Transformation ratio (PT ratio) | 33 kV / 110 V / √3 V |
| 6 | Rated Output (V.A. burden) | 50 VA per phase |
| 7 | Impulse withstand voltage (kV peak) (on assembled PT) | 150 |
| 8 | One minute power frequency dry withstand voltage (on assembled PT set | |

| | | |
|---|---|---|
| | Primary (KV RMS)<br>Secondary (KV RMS) | 70<br>3 |
| 9 | Class of accuracy | 0.2 |
| 10 | Rated voltage factor and time | 1.2 times continuous and 1.5 times for 30 sec. |
| 11 | System conditions | Effectively earthed system |
| 12 | Maximum temperature raise over maximum ambient temperature (which may be taken as 45) | Within limits of IS 3156 with latest amendments/revision |
| 13 | Maximum ratio error | Do |
| 14 | Maximum phase angle error | Do |

### 7.2.2 11 KV System

### 1. General

a) There is a 11 KV GIS panel in the 33 KV grid substation at each portal The 11 KV GIS panel configuration shall have following feeders as per SLD drawing.

b) At Grid station(North and South Portal):

i. 11KV GIS Panel (Grid)

- nos. incomer from 2 nos. Power transformers through 11 KV XLPE cable.
- nos. incomer from 11KV DG Sync Panel through 11 KV XLPE cable.
- 1 no. bus coupler.
- 2 no. outgoings for Ring feeder 1 & 2
- 2 no. Spare feeders
- 11 KV GIS panel (For DG System) will have following feeders:
- 2 nos. incomers from 2 nos. DG Sets through 11 KV XLPE cable.
- 2 no. outgoings to 11KV GIS Panel(Grid)
- Spare feeders

### 2. Scope of Work

The high voltage supply system shall include the delivery, installation, required works, tests and all necessary equipment for the following materials:

- 11 kV switchgears (panels / cubicles)
- 11 kV cables
- Protection system
- Instrument Transformers
- Accessories
- Potential Equalisation connections
- Wiring and signalling for 11kV

### 3. Technical Specification – 11kV GIS (11kV GAS-Insulated, Switchgears)

(A) Indoor 11kv Modular, Gas-Insulated, Switchgears

(a) BASIC SWITCHGEAR DESIGN

i. A metal-enclosed, gas-insulated switchgear according to the currently applicable standards and provisions, prefabricated and type-tested, as single busbar system with stationary switching devices is to be implemented.

ii. The switchgear shall consist of modules, to be aligned side by side, to minimize the number of components subject to high electrical loads. The individual modules correspond to the single line, and the function units described below. The modules must also be connected so that the entire busbar assembly is completely enclosed in SF6 gas atmosphere. Possible extension: on both sides. The IEC classes of the applicable standards and regulations must be specified in the offer and proved by test records.

(b) ECOLOGICAL CORRECT CONSTRUCTION

i. The switchgear must satisfy to a high degree the ecological requirements in view of environmental protection.

ii. The consumption of material and energy during production is to be minimized in an optimum fashion. This applies especially to the utilization of insulating material. Ecologically safe, low-maintenance operation with a service life of min. 30 years must be possible. Use of recyclable materials for efficient and complete (100%) disposal at the end of the service life must be proved by a utilization data sheet. The offer must be accompanied by a certificate confirming that the quality requirements acc. to DIN ISO 9001 have been complied with. After the course of operational switchboard life, it must be possible to recover the complete SF6-gas of every gas-filled compartment by a serial recover valve. Special equipment of the switchboard supplier for recovering is permitted.

(c) GAS COMPARTMENT TECHNOLOGY AND GAS COMPARTMENT MONITORING

i. The cladded gas compartments must be filled with the insulating gas SF6 and be designed as hermetically sealed pressure system according to IEC 60694 (IEC 62271-1), IS-12729-2004. The switchgear's high degree of leak-proofness regarding gas is to ensure that no insulating gas has to be added during the expected service life of the switchgear, under the normal operating conditions specified for indoor switchgear units. The complete busbar system, a central element of the switchgear, must be integrated completely and throughout within the gas-filled cladded compartment of the switchgear. The gas compartments are monitored via pressure gauges with remote signaling contact.

ii. To ensure maximum reliability and availability of the switchgear, the number of gas compartment seals, of static bushings and pressure relief devices must be kept to a minimum. All three breaker poles of a switching device should have a common, gas-tight rotary bushing. The gas compartments must be welded, and all static bushings must be sealed by pressure gaskets for operational life. The operational leak rate for gas insulation must not exceed 0.1 % per year and manufacture to guarantee no gas handling at a site during extension, removal and installation of at site.

(d) PRESSURE RELIEF FOR THE CLADDED GAS COMPARTMENTS

i. The pressure relief device of each gas-filled cladded compartment should be affected via appropriate relief devices into a pressure relief area on the underside of the module. This pressure relief area must be partitioned against the cable connection compartment using a metallic cover. The preferred direction for pressure relief is, from the cable connection compartment to the bottom / top rear, and from the gas compartment of the module tank to the top rear / bottom. Appropriate flooring ducts are prepared by the Customer according to the Concessionaire's specifications before switchgear installation on site.

(e) DESIGN

i. The switchgear must be designed with extremely small dimensions and for minimum space requirements.

(f) LOW-VOLTAGE CABINET

i. Each function unit is to be equipped with a separate, closed, fully shrouded and arc-resistant low-voltage cabinet with mechanical and electrical interface to accommodate digital protection relays and secondary equipment for control, measurement and counting/metering. The torsion-resistant door can accommodate devices. The dimensions of the low-voltage cabinet have a minimum height of 600 mm and a minimum depth of 350 mm. For transport reasons the low-voltage cabinet must should be easily removable and mountable. Mechanical drive elements must not be installed in the low-voltage cabinet.

(g) ON-SITE INSTALLATION AND POSSIBLE EXTENSION

i. The individual modules or cubicles must be designed so that they can be lined up on site without any problems or work involving gas bottles. The in-line modular design is to reduce assembly time as much as possible. The specifications dictate that the switchgear must be designed so as to allow for subsequent extension without problems,

without requiring interventions into the existing modules. This must be documented conclusively, e.g. by operating manuals and installation instructions.

(h) INTERNAL ARC CLASSIFICATION (IAC)

i. The switchgear to be offered must be checked successfully for internal arc classification. To this effect, the currently applicable standards and provisions must be complied with. The proven short-circuit current must be at a minimum related to the value of the rated short-time current 25kA. The short-circuit duration is 3 s. The test report must be shown with the offer. The following arcing locations must have been realized in the scope of successful testing: gas-filled cladded compartment, preferably in the area of the outer cone-type bushings for cable connection busbar area / coupling chamber between the modules cable connection compartment.

(i) INTERLOCKING SYSTEM

To ensure maximum operator safety, the switchgear must be equipped with a comprehensive interlocking system of excellent design. This interlocking system is to integrate the cable connection compartment and the HVHRC fuse compartment systematically. Actuation of the mechanical operating lever should follow the interrogation interlock principle.

(j) MECHANICAL INTERLOCKS

i. The interlocking system regarding mechanical operating lever actuation must be designed according to the interrogation interlock principle. This means that an operating lever can only be inserted or that actuating forces may only act on the components if this is permitted by the appropriate operating condition of the function unit in question. Digital switchgear interlock units are not accepted by the Customer due to their high costs and as these systems depend on the switchgear's auxiliary voltage.

ii. The interlocking system used should comply with the following interlocking conditions, depending on the equipment installed:

- Double-acting interlock between busbar isolator and outgoing earthing switch
- Double-acting interlock between busbar isolator and circuit-breaker
- Double-acting mechanical interlock between the switch disconnector and the outgoing earthing switch
- Double-acting interlock between the cable compartment cover and the outgoing earthing switch(es) (for cable testing, specific equipment must be provided to eliminate the outgoing earthing)
- Double-acting mechanical interlock between the coupled outgoing earthing switches and the metallic fuse covers
- The fuses are only accessible when the earthing switches are ON
- The front cover can only be closed if the fuses are inserted correctly
- It must only be possible to remove or insert actuating levers in clearly defined positions

(B) "CLOSE" or "OPEN"

(a) VOLTAGE DETECTING SYSTEM ACCORDING IEC 61243-5(CAPACITIVE VOLTAGE INDICATOR)

The test for zero voltage is performed by a plug-in Voltage Detecting System (VDS), which complies with the applicable standards and provisions. Coupling is affected from capacitive voltage dividers in the cable connection areas. Appropriate connections must be provided to enable phase comparison; these are covered in normal operating condition.

(b) TRANSFORMERS (VOLTAGE / CURRENT TRANSFORMERS)

Inductive current and voltage transformers with minimum amounts of insulating material must be used. It must be possible to operate all commercially available, digital protection relays with the transformers.

(c) CURRENT TRANSFORMER

CT is to be equipped in the outgoing circuit of the circuit-breaker units, with low-voltage ring core current transformers which are separately accessible in the cable connection compartment and which must be mounted outside of the gas compartment onto the extended outer cone-type bushings. Retrofitting or replacing of the current transformers is possible without intervention in the gas compartment from the switchgear front side. The measuring

and protection cores are located in a common transformer block. For normal current measurement, the switch disconnector unit can be equipped with one cable-type current transformer per phase. These transformers are located in the metal-enclosed cable connection compartment. The power ratings of the cores must be dimensioned according to the measuring and protection equipment connected to them.

(d) VOLTAGE TRANSFORMERS

1) Metal-enclosed or metallized, touch proofed and grounded inductive voltage transformers should be used. Voltage transformers on the busbars are directly plug-in to the switchgear outside of the gas- filled compartments.

2) Instrument transformers shall be suitable for continuous operation at the ambient temperature prevailing inside the switchgear enclosure, when the switchboard is operating at its rated load and the outside ambient temperature is 45 deg. C.

3) Feeder voltage transformers must be disconnectable using a ON-OFF switch to perform cable tests without having to remove the transformers.

4) Busbar voltage transformers must be designed to withstand 80% of the power-frequency withstand test voltage to enable repeat tests at the busbar without having to remove the transformers.

5) Current/voltage sensors, Rogowski coil and or other non-standard arrangement are not acceptable.

6) HT Fuse are not acceptable for Voltage Transformer.

(e) CORROSION PROTECTION AND PAINTING

Corrosion-prone steel components of the switchgear cubicles – unless they are made of stainless steel – must be protected by zinc phosphate. Large-sized front components visible from the outside, such as doors or covers, should be coated additionally by scratch-proof textured paint. The colour coating should be provided in the colour RAL 7044 (silk grey).

(f) CIRCUIT BREAKER

i. Circuit breakers should be Vacuum type. They should be according to IEC 62271-100 standard. Rated operating sequence must be O-3 Min-CO-3 Min-CO. Operating time for opening, breaking less than 80ms and closing, less than 60ms. Circuit breaker must be E2/M2/C2 type (electrical, mechanical endurance and capacitor breaking/making ability) according to relevant standards. Vacuum Interrupter shall be tested for min. 100 nos. of full short circuit operations at a rated fault level. The circuit breaker operating mechanism will be outside the SF6 tank, manually and electrically operated. Vacuum interrupters must be GIS manufacturer's own make and should be type tested design. The operating mechanism should consist in the following items.

a) Spring system that stores the necessary energy for opening and closing operation.

b) Spring charging system (motor operated) that automatically recharges the springs after the main contacts of the CB have closed.

c) Mechanical "charged-discharged" position indicator for CB opening and closing springs.

d) Manually operated spring charging system (in case of lack of auxiliary power supply).

e) Electrical system including:

f) Tripping coil

g) Anti-pumping relay

h) Mechanical emergency trip pushbutton.

i) Operation counter

j) Spring charging indication contact.

k) Mechanical indicator for Open / Closed position

l) Minimum CB position auxiliary contacts

(g) DISCONNECTOR

i. The Disconnector is a mechanical device which provides, in the open position, an isolating distance. The Disconnector is always operated with NO LOAD (zero current). The Disconnector will be placed between the CB and the busbar system in order to isolate the busbar system from the circuit side and earth the CB busbar terminals. The Earthing

Disconnector will operate always de-energized, and the making capacity is provided by the circuit-breaker, which is designed for these purposes.

ii. The Disconnector must be according to the latest edition of the IEC 62271-102 and shall meet requirements as specified in RATINGS. The indication of the position of the Disconnector must be mechanical. This mechanical link must be kinematic chain tested. The Operating mechanism must be outside the SF6 atmosphere and accessible from the front.

iii. As the Disconnector is not for operating purposes, the local manual operation by the operator is advisable against the remote-electrical one. Therefore, only manual operation is necessary. The Disconnector must be of single common rotation-driving axis both for the Disconnector and the Earthing switch. It is mandatory that the operation from "closed to busbar" to "ready to earth" is made in two separate operations, closed - open and open - ready to earth. These are completely independent operations, with two separated operating access.

(h) BUSBAR

Busbar shall be single phase solid insulation, screened and earth through the whole switchboard, in order to:

i. Reduce the SF6 quantity in all cubicles.

ii. Maintain the advantages of SF6 insulation not affected by ambient condition.

iii. Reduce the possibility of a phase-to-phase fault.

iv. Reduce the dimensions.

v. Provide the possibilities of installing measuring instruments directly in the busbar system.

(i) EARTHING THE SYSTEM

1) A copper / aluminium earth bus of suitable size shall be provided at the bottom extending through the entire length of switchgear. Each stationary unit of the cubicle shall be earthed directly to the earth bus through a contact bar so that the carriage is earthed at all times except when the primary disconnects are separated by a safe distance. Suitable clamp type connectors shall be provided at both ends of the earth bus to suit external earthing conductor. Also hinged doors of the cubicle base plate of C/T and P/T shall be effectively earthed. Earth bus shall protrude outside the extreme end panels and by at least by 100 mm.

2) One set of earthing accessories shall be supplied with the switchgear for earthing of the outgoing side of a feeder or 3 phase bus bars of the switchgear either through earthing facility comprises truck to be inserted in place of circuit breakers, separate earthing trucks shall be supplied where earthing is achieved through circuit the earth device unless the circuit-breaker is in open and isolated position.

(j) LOW-VOLTAGE EQUIPMENT

1) INDICATION AND ALARMS: All the specific indications and alarms, which are relevant for the switchgear, must be wired to terminals.

2) REMOTE CONTROL: The remote control for the switching devices in the motor drive must be designed as lockable via a REMOTE ON-OFF switch. Each function unit concerned must be equipped with a remote on-off change-over switch.

3) NUMERICAL RELAY:

a. Numerical relay shall be of modular type and have native IEC 61850 communication support for RTU/SCADA integration. Relay shall be with graphical LCD dot matrix display with single line diagram mimic with control, indication, programmable function key and LEDs.

b. Relay shall have adequate following protections (50/51, 50N/51N, 46, 86, 50ARC, 50NARC as native function). Arc Flash protection shall be an integral part of relay. Protection relay hardware, cables and separate arc sensors shall be included. Any arc flash fault in the cable compartment is selectively cleared by the feeder protection relay.

c. The relay should be with G3 conformal coating and suitable to work in Industrial corrosive environment and should have passed mixed gas test as per IEC 60068-2-60:1995, Part 2, Test Ke, Method (Class 3). The test to include 21 days at 75% relative humidity or 5days at 90% relative humidity and +30 deg C, exposure to elevated concentrations of H2S, NO2 and CI2.

## 4. 11KV RING MAIN UNIT (RMU)

(1) GENERAL SPECIFICATIONS

i. RMU type, metal-enclosed indoor switchgears, shall be compact switchboard and comply to the following requirements:

- Easy to install
- Safe and easy to operate
- Compact
- Low maintenance

ii. The RMU shall be capable of operating normally within the following temperature range:

- Maximum air temperature: + 40 ° C
- Minimum air temperature: - 5 ° C

iii. RMU to operate in air temperature higher than + 40 °C and the level of air temperature for which current derating is necessary.

iv. The RMU shall be capable of being operated in electrically exposed locations.

v. The RMU shall be capable of being exposed to high relative humidity and ambient air pollution.

vi. The RMU shall be capable of being installed in either concrete indoor substations or in compact metal substations and kiosks with an IP67 rating.

(2) FUNCTION REQUIREMENTS

vii. The following functions shall be available:

- Feeder with switch-disconnector
- Transformer protection with vacuum circuit breaker

viii. Enclosure:

The RMU enclosure shall be made up of CRCA of 2 mm thickness. The high-voltage gas vessel shall be made up of non-magnetic stainless-steel grade SS304 or higher with minimum thickness of 2.5mm. The rating of enclosure shall be suitable for operation on three phases, three wire, 11 KV, 50 cycles, A.C. System with short-time current rating of 21 kA for 3 seconds with Panels. The complete RMU enclosure shall be of degree of protection IP 54. The enclosure shall provide full insulation, making the Switchgear insensitive to the environment like temporary flooding, high humidity etc. The active parts of the Switchgear shall be maintenance-free, and the unit shall be minimum - maintenance.

ix. The Switchgear and Switchboards shall be designed such that the position of the different devices is visible to the operator on the front of the Switchboard and operations are visible.

x. The RMU metal parts shall be made of high thickness high tensile steel which must be treated with 7 tank treatment and subsequently painted with pure polyester, the overall paint layer thickness shall be 100 microns (+/- 25 Micron).

xi. Configuration requirements

a) Extensible range:

b) function unit:

c) Switch-disconnector - Switch-disconnector - Transformer protection with vacuum circuit breaker

d) The RMU shall meet the criteria for compact, metal-enclosed indoor switchgear in accordance with

e) IEC 62271-200:

f) Switchgear classification: PM class

g) Loss of service continuity class: LSC2

h) It shall include, within the same metal enclosure, the number of MV functional units required for connection, power supply and protection of transformers.

(3) RMU BUSHINGS AND CABLE TERMINATIONS

(a) Bushing

i. It is preferable to have all bushings accessible from the front of the RMU and should be site replaceable type. Bushings along the sides or the rear of the RMU are not acceptable.

ii. For each cable compartment, the bushing shall be at the same height in order to facilitate a possible reversal of the cables

iii. The bushing should be conveniently located for working with cables specified and allow for the termination of these cables:

- 630 A M16 bolted connectors for switch-disconnectors and vacuum circuit breakers functions
- 200 A plug-in connectors for transformer protection feeder with fuse combination.

iv. The profiles of the cable connection bushings shall be in compliance with IEC-60137, IS-2099, IS-10314, IS-5621, IEC-60137 standard.

v. A cable clamp arrangement must be provided for all network cables terminated on the RMU.

(4) PADLOCKING FACILITIES

Circuit breakers, fuse-switches combination, switches and earthing switches can be locked in the open or closed position by at least 1 padlock.

(5) VOLTAGE INDICATORS AND PHASE COMPARATORS

i. Each function shall be equipped with a voltage indicator box on the front of the device to indicate whether or not there is voltage in the cables. The capacitive dividers will supply low voltage power to the lamps.

ii. Three inlets can be used to check the synchronization of phases.

iii. This device shall be in compliance with IEC 61958 standard or IEC 61243-5.

(6) FAULT PASSAGE INDICATORS (FPI)

i. The FPI shall facilitate quick detection of faulty section of line. The fault indication may be on the basis of monitoring fault current flow through the device. The FPI should be self-powered and should have internal lithium battery for external indication and setting of FPI in the absence of current.

ii. The FPIs shall include:

iii. Fault detection - Phase to phase and Phase to earth faults.

iv. One potential-free output contacts for hardwiring to RTUs. On this basis, the SCADA will be able to monitor phase / earth fault condition.

v. Local fault indications - LCD display on FPI front panel along with LED indication on front panel of RMU enclosure.

vi. Multiple reset option –

- End of time delay
- Remote reset (Via potential free input contact of FPI)
- Manual reset (Reset button on front panel of FPI)
- Automatic reset on current restoration.

vii. The characteristics of the FPIs shall include:

- Phase fault thresholds configurable from at least 100 to 800 A
- Earth fault thresholds configurable from at least 20 to 200 A
- Multiple number of steps for adjusting phase and earth fault thresholds.
- Fault current duration range configurable

viii. RMU should have VCB and interrupter of the same make of the RMU .

(7) SAFETY OF PEOPLE

Any accidental overpressure inside the sealed chamber will be limited by the opening of a pressure limiting device in the lower part of the enclosure. Gas will be released to the rear or the bottom of the switchboard away from the operator. Manufacturer shall provide type test report to prove compliance with IEC 62271-200 Annex A, Internal arc classification class AFL with 21kA for 1s for the SF6 tank and cable box..

(8) OPERATING LEVER

An anti-reflex mechanism on the operating lever shall prevent any attempts to reopen immediately after the closing of the switch or earthing switch. All manual operations will be carried out in the front of the switchboard.

(9) FRONT PLATE

i. The front plate shall have suitable IP degree of protection. The front shall include a clear mimic diagram which indicates the different functions.

ii. The position indicators shall give a true reflection of the position of the main contacts. They shall be clearly visible to the operator.

iii. The lever operating direction shall be clearly indicated in the mimic diagram.

iv. The manufacturer's plate shall include the switchboard's main electrical characteristics.

(10) CABLE INSULATION TESTING

i. It must be possible to test the core or the sheath insulation of the network cables while the busbar remains energized at rated voltage. The phase by phase testing shall be carried out through a built-in facility or through the cable connectors.

ii. In order to avoid any risk of bad reassembly, it shall not be necessary to dismantle any earthing bar to perform this operation

(11) REMOTE CONTROL OF THE RMU'S

i. A limited number of applications for remote operation of the RMU are required.

ii. Remote operation of the RMUs line switches must be possible using motors fitted to the operating mechanism.

iii. It shall be possible to fit the motors either directly in the manufacturing plant or on site when required. Installation on site shall be possible with the RMU fully energized and the manufacturer should provide detailed instructions for installation to the control mechanism. Auxiliary contacts for remote indication of switch status are also required.

iv. The fitting of the motors to the mechanism must not in any way impede or interfere with the manual operation of the switches. An auxiliary contact to prevent the motorized operation of the mechanism while the operating handle is inserted into the operating point must also be provided

v. The device shall be fully designed for use in a hot, humid atmosphere and shall be low-maintenance. All metallic parts shall have rust protection.

vi. Two lifting rings shall be installed on the top of the switchboards for handling.

(12) TYPE AND ROUTINE TESTS

i. The switchboard, to comply with the following tests (but not limited to):

a) Impulse withstand test,

b) Temperature-rise test,

c) Short time withstand current test,

d) Mechanical operation test,

e) Checking of degree of protection,

f) Switch, circuit breaker, earthing switch making capacity.

g) Switch, circuit breaker breaking capacity.

h) Internal arc withstand

i) Checking of partial discharge on complete unit

ii. The test certificate to conform to NABL accredited testing lab certificate for carrying out internal inspection and testing. The manufacturer must carry out testing of the panel at NABL accredited testing lab or international lab.

iii. The routine tests shall be backed by test reports and include the followings to conform with drawings and diagrams,

a) Measurement of closing and opening speeds,

b) Measurement of operating torque,

c) Checking of filling pressure,

d) Checking of gas-tightness,

e) Checking of partial discharges on individual components,

f) Dielectric testing and main circuit resistance measurement.

(13) 11kV SWITCHBOARDS

a) The switchgear and busbar shall meet the "sealed pressure system" criterion in accordance with the IEC 62271. The manufacturer certificate shall confirm that maximum leakage rate is lower than 0.1 % / year.

b) It shall provide full insulation, for switchgear insensitive to the environment (temporary flooding, high humidity, etc.), IP67 degrees of protection in accordance with recommendation IEC 60529 § 14.2.7.

c) The switchgear shall be maintenance-free and the switchboard shall be low-maintenance.

d) The switchboards shall be suitable for IP protection.

e) The cable compartment shall integrate:

i. Adjustable cable fixing devices

ii. Earth connecting point

iii. Metal partition between cable compartments and tank pressure relief area.

f) The cable compartment shall be arc resistant and suitable for the following cable connecting systems:

i. Partial insulated cable connectors

ii. Fully screened cable connectors

iii. Metal enclosed cable connectors according to DIN EN 50181, IS-2099, IS-10314, IS-5621 and IEC-60137.

g) The colour shall be RAL 7035 as approved for the enclosure and mimic panel.

h) The switchgear and switchboards shall be designed so that the position of the different devices is visible to the operator on the front of the switchboard and operations are visible as well.

i) In accordance with the standards in effect, switchboards shall be designed so as to prevent access to all live parts during operation without the use of tools.

(14) EARTHING OF METALLIC PARTS

a) There shall be continuity between the metallic parts of the switchboard and cables so that there is no electric field pattern in the surrounding air, thereby ensuring the safety of people.

b) The substation frames shall be connected to the main earth busbar without dismantling any bus bars.

(15) EARTHING OF THE MAIN CIRCUIT

a) The cables shall be earthed by an earthing switch with short-circuit making capacity, in compliance with IEC 62271-102 standard. The earthing switch can only be operated when the switch is open.

b) The earthing switch shall be fitted with its own operating mechanism and manual closing shall be driven by a fast-acting mechanism, independent of operator action.

c) Mechanical interlocking systems shall prevent access to the operating shaft to avoid all operator errors such as closing the earthing switch when the switch is closed.

(16) FEEDER WITH SWITCH-DISCONNECTOR

a) They shall be maintenance-free. The position of the power contacts and earthing contacts shall be clearly visible on the front of the switchboard. The position indicator shall provide positive contact indication in accordance

with IEC 60265-1 & IS-9920 (Part-1)-2002 standard. In addition, manufacturer shall prove reliability of indication in accordance with IEC 62271-102 § 6.105 standard.

b) The switches shall be of the "increased operating frequency" in accordance with IEC 60265-1 § 3.104 standard. They shall have 3 positions, open-disconnected, closed and earthed, and will be constructed in such a way that interlocking prevents unauthorized operations. The switch-disconnector and earthing switch shall be equipped with two separate operating entry points.

c) Manual opening and closing will be driven by a fast-acting mechanism, independent of operator action.

d) Each switch can be fitted with an electrical operating mechanism in a specially reserved location, by addition of a motorization unit and without de-energizing the switchboard.

e) The switch and earthing switch operating mechanism shall have a mechanical endurance of at least 1000 operations.

(17) TRANSFORMER PROTECTION WITH VACUUM CIRCUIT BREAKER

a) The circuit breakers shall be of the maintenance-free, vacuum type. The position of the power and earthing contacts shall be clearly visible on the front of the switchboard. The position indicator shall provide positive contact indication in accordance with IEC 62271-102 standard and prove reliability of indication in accordance with IEC 62271-102 § 6.105 standard.

b) An operating mechanism can be used to manually close the circuit breaker and charge the mechanism in a single movement. An independent mechanism shall be fitted for the 3-position earthing switch and disconnector and include a local system for manual tripping by an integrated push button. The operating sequence of vacuum circuit breaker must be O-0.3sec-CO-3min-CO and mechanical endurance shall be 10000 nos of operation without any maintenance.

c) The circuit breaker shall be associated with an integrated protection unit that will operate without any auxiliary power supply and shall include:

i. Three toroidal transformers incorporated in the transformer tee-off bushings for protection and metering,

ii. An electronic relay (Self Powered)

iii. A low energy release

iv. A system protection testing (with or without CB tripping)

(18) MV METERING

a) MV Metering shall be carried out by a factory assembled.

b) Connection with adjacent cells will be direct through bus bar but MV cables shall be possible.

c) VT's and CT's to comply with type DIN 42600 standards and IS-3156, IS-2705, IS-16227 and the following configuration shall be available:

i. VT's phase-earth

ii. -1 nos. Aux VT , 1ph, 500VA, 11KV/230V AC

(19) FEEDER REMOTE TERMINAL UNIT (FRTU)

a) The RMU remote control interface shall include all the functions required to monitor and control LBS and VCB in RMU.

b) Since, requirement is for Motorized RMU ,and looking at integration issues same vendor to supply FRTU and RMU and support for integration of FRTU with Scada, in order to avoid teething technical issues of integration while execution.

c) The monitoring and control enclosure shall meet following main requirements:

i. Monitoring and control of medium voltage cubicles.

ii. Detection of amperometric faults, adjustable for each feeder.

iii. Load current measurement to the SCADA.

iv. Data transmission to the remote control centre.

v. It shall be possible to view the most important information locally on the front panel of the enclosure and remotely from the control centres.

vi. Possible to retrieve and display on a laptop PC the time-stamped events recorded at the

vii. enclosure. Possible to retrieve information from the remote control centre also.

viii. Event storing capacity.

ix. Local remote switch

d) In remote control mode, the enclosure shall ensure:

i. Transmission of remote measurements and time-stamped events.

ii. Possibility of electrical remote control.

iii. Inhibition of local electrical control pushbuttons.

e) In local mode, the enclosure shall ensure:

i. Transmission of remote measurements and time-stamped events.

ii. Possibility of local electrical control of opening and closing operations by simultaneously pressing a pushbutton to select the unit to be operated and a validation pushbutton.

iii. Inhibition of opening/closing remote control.

(20) FRTU POWER SUPPLY:

a) Power from FRTU shall be sufficient to supply 24 V to at least all the switch cubicles.

b) The standby energy shall be provided by a 12 V 24 Ah battery / as approved with a minimum autonomy of at least 9 hours for 10 opening and closing cycles.

c) The FRTU power supply shall be protected against over voltages and over currents. The dielectric characteristics of the supply voltage input in accordance with IEC 60 25564 shall be available in the station is single-phase 220 V AC.

d) The control unit shall comply with the following communication ports:

i. One Ethernet port for interfacing with IP compatible communication equipment.

ii. One Modbus RS485 port to connect field IED's / Energy Meters on RS485.

iii. One port for connecting external modems.

TABLE: 1 TECHNICAL DATASHEET FOR RING MAIN UNIT (RMU)

| | |
|---|---|
| Network | Three phases - Three wires |
| Rated Voltage | 12 kV |
| Service Voltage | 11 kV |
| System Frequency | 50 Hz |
| Lightning Impulse withstand Voltage<br>Phase to phase, phase to earth<br>Across the isolating distance | <br>75kV<br>85 kV |
| Power Frequency withstand voltage | 28 kV rms - 1 min |
| Rated Normal Current<br>Line switch | <br>630 A |

| | |
|---|---|
| Transformer feeder<br>Branch circuit breaker feeder | 200 A<br>630 A |
| Rated Short time current withstand ( 3 sec ) | 21 kA |
| Internal Arc IAC (SF6 tank and cable box) | 21KA for 1 sec with AFLR classification |
| Rated Short circuit making capacity of line switches and earthing switches | 62,5 kA peak at Rated Voltage |
| Number of operations at rated short circuit current on line switches, earthing switches and CB | 5 closing operations |
| Rated load interrupting current<br>Line switch | <br>630 A rms |
| Rated cable charging interrupting current<br>Line switch | <br>30 A |
| Number of mechanical operations<br>Line switches and earthing switches<br>Switch-fuse combination<br>Circuit breaker | <br>1000 O/C<br>1000 O/C<br>2000 O/C |
| Number of electrical operations at full load breaking current | 100 O/C |
| Number of operations at rated short circuit<br>current on circuit breaker | <br>10 breaking operations |

All of the switchgears shall be capable of withstanding this current without any damage being caused, in accordance with the recommendations IEC 62271-1 and IEC 62271-200.

## 5. Protection System Of 11 KV System

a) For the protection of the high voltage equipment, over current-time protection relay with feeder differential protection for cable connections shall be provided. Backward-lock-out shall shorten the time to trip.

b) During failure of time-overcurrent protection, a selective time interval, which is another type of protection trips, shall be provided.

c) A synchro-check unit shall be provided for the circuit breakers in the 11 kV feeder and cable panels. With this synchro-check unit the state at switching points shall be controlled for enabling an uninterrupted switching to normal net configuration in case of a failure.

d) All required OFC equipment for the protection system of 11 kV System shall be included in the price of protection system.

## 6. SPECIFICATION OF PROTECTING SYSTEM:

a) By the protection system of the High Voltage Supply, the Concessionaire has to take into account, that an Electrical selectivity/discrimination between the individually (sub) stations and the 33 kV-System shall be provided.

b) Basic conditions for the protecting systems are:

i. Selectivity to the 33 kV-System

ii. Selectivity by faults in cables with automatic shift of the disconnecting point to the defect part of the system

iii. Insensitive and reliable protection system for tunnels

iv. Internal data-transmitting via optical fibre cabling

## 7. CURRENT TRANSFORMER

Current transformers for feeder panel or cable panels shall be three-pole, provided with measuring and protecting core. In the cable panel, toroidal core transformers shall be used provided as a three-phase block-type current transformer. The current transformer load shall be adjusted to the arrangement of protection devices. The secondary terminals shall be situated on the terminal strip inside the panel.

## 8. VOLTAGE TRANSFORMER

For voltage measuring on the bus bar, three one-pole voltage transformers shall be used.

For cable panels, three one-pole voltage transformers shall be used for measuring and earth- fault detection, with open delta winding. All voltage transformers shall be pluggable, metal- enclosed and shock proofed. The secondary terminals shall be realized by plugs inside the panel. Voltage transformers on the branch shall be removable for cable testings.

## 9. PROTECTION EQUIPMENT

All functions of the protection equipment shall be microprocessor controlled (microprocessor- based protection and control).

## 10. AUXILIARY POWER SUPPLY

For the required auxiliary power supply, a connection E&M Concessionaire's DC power supply shall be included. The power supply of the protection equipment shall be able to span an interruption of the auxiliary supply for ≤ 50 ms. A switching of ON / OFF of the auxiliary power supply shall not cause a malfunction of the protection equipment.

## 11. PILOT RELAY

For the transmission of signals, the Concessionaire shall provide enough pilot relays. The assignment of the signals to the relays shall be freely selectable. Also the formation of common signal / common alarm shall be possible. The state of the relays shall survive a failure and recovery of the auxiliary supply.

## 12. STORAGE OF FAULT SIGNALS AND FAULT VALUES / ALARMS

The formed fault signals in the devices of the last three events shall be stored by SCADA. The beginning of a failure shall be marked with the real-time of the internal system clock. Within failure the separate signals shall be provided with the relative time with a resolution of 1 ms.

## 13. DATE AND TIME

All protection devices shall be equipped with integral real-time clock (RTC) inclusive a calendar function. The clock shall be able to be synchronized and equipped with a buffer battery.

## 14. SELF-MONITORING AND SIGNALLING OF DEVICE-FAULTS

a) All protection devices shall be equipped with monitoring of the hardware and software. Minimum requirement of the monitoring is:

i. Monitoring of the internal auxiliary power supply for digital and analogue circuits

ii. Monitoring of the analogue-to-digital conversion (offset, drift, accuracy)

iii. Monitoring of the command circuit to the coil of the command relays (short circuit and failure / interruption)

iv. Monitoring memory chips by using cyclic formation of checksum and comparing with deposited checksum.

v. Monitoring of the continuous program processing by time monitoring (watchdog)

## 15. FURTHER REQUIREMENTS

a) The protection devices shall be designed as panel-plug-in devices with screw-type terminals on the back side and covering, and following front side display and control elements (minimal requirement):

i. Illuminated LC-display, (at least) four lines, alphanumeric, for displaying of miscellaneous. information

ii. at least 6 free parametrizable LED displays with labelling field

iii. at least 4 free programmable function keys

iv. 4 navigation keys

v. at least 12 numeric operator buttons

vi. special keys for parameterization

## 16. OVERCURRENT – TIME PROTECTION RELAY WITH FEEDER DIFFERENTIAL PROTECTION FOR CABLE CONNECTIONS

a) Nominal current: 1 A

b) Nominal voltage: 80 – 125 V

c) Nominal frequency: 50 Hz

d) Auxiliary power supply: 240 VAC

e) Local control:

- 4-lined LCD-display with information text
- Indication and count value
- Operator and control keyboard
- 4 free programmable function keys
- 7 free programmable LEDs

f) Communication:

- Interface RS232 on the front side
- System-Interface on the backside of the device
- Interfaces for optical fibre cables (amount and types depends on used system)

g) General functions:

- Battery-maintained clock
- Fault messages: the last 8 fault messages have to be stored
- Operational message: the last 80 messages have to be stored
- Self-monitoring

h) In-/Outputs:

- 7 binary inputs
- 5 relay outputs
- 1 live contact

i) Protection functions:

- Phase-selective differential protection for two-ending-operation
- Over current-time protection phase I>, I>>, Ip>>
- Breaker intertripping
- Thermal overload protection
- Quick breaking step
- Displaying of measurements for local and distant cable-endings
- Operation by parameters
- Lock-out
- Trigger circuit protection

j) Automatic functions:

- Command conversation
- Filter for messages
- Locking transfer function
- Programmable logical functions

## 17. OVER CURRENT TIME PROTECTION FOR OUTGOING TRANSFORMER UNIT

a) Nominal current: 1 A

b) Nominal frequency: 50 Hz

c) Auxiliary power supply: 240 VAC

d) Local control: LCD-display for current measurements

e) Communication:

i.Interface RS232 on the front side

ii.System-Interface on backside of device

f) Interfaces for optical fibre cables (amount and types depends on used system).

g) General functions:

i.Battery-maintained clock

ii.Fault messages: the last 8 fault messages have to be stored

iii.Operational message: the last 80 messages have to be stored

iv.Self-monitoring

h) In-/Outputs:

i.7 binary inputs

ii.5 relay outputs

iii.1 live contact

i) Protection functions:

i.Over current-time protection phase I >, I >>, Ip >>

ii.Over current-time protection earth IE >, IE >>, IEp >>

iii.Inrush locking

j) Automatic functions:

i.command conversation

ii.Filter for messages

iii.Locking of transfer function

iv.Programmable logical functions

## 18. Accessories For 11 KV System

(A) DISTRIBUTED I/O (PROVIDED BY CONCESSIONAIRE OF E&M / SCADA)

Distributed I/O's are required for using the advantages of a double-sided feeding at the 11 kV System. The distributed I/O's will be provided by the Concessionaire of E&M/SCADA. All data points of the 11 kV-System run to the distributed I/O's .

(B) FIRE EXTINGUISHER

a) CO fire extinguishers shall be provided in E & M Niches, equipment room / Niches substation.

b) The fire extinguishers shall be made of galvanized steel and resistant against frost. Dry powder extinguishers only in rooms with lower voltages than 1 000 V are allowed. So, in the high voltage rooms CO2-fire extinguishers shall be required.

(C) ACCESSORIES FOR 11KV (SUB) STATION

a) Each 11 kV (sub) station shall be equipped with:

i. Single Line Diagram of 11 kV-System of tunnel with glass-covering

ii. Sheet / Board including the instruction for first aid by electrical accidents

iii. Sheet / Board including the instructions for fire-fighting measures in electrical plants

iv. Prescription of operation of High Voltage Systems

v. Suspension Device for accessories

vi. Warning Sign "Attention High Voltage"

vii. Voltage Detector

viii. Earthing Accessories

## 19. Operation Modes

All switching equipment, which shall be equipped with a remote-control switch, shall need a changeover switch. Therewith a switching between local- or remote-control is possible.

LOCAL CONTROL:

If the changeover switch is positioned at "local control", all up streamed switching equipment has to switch off the remote controlling. The whole switchgear interlocking shall also work at local control.

REMOTE CONTROL:

a) At this position of the changeover switch the user shall be able to choose between different switch possibilities out of a predefined matrix. Generally, it shall be possible to decide which of the two feedings shall be switched.

b) A remote controlling of the high voltage power supply shall only be possible, if:

i. No changeover switch is positioned at local control.

ii. No earthing switch is switched.

iii. No fault is stored.

Table 5: TECHNICAL DATASHEET FOR 11KV GAS INSULATED SWITCH-GEAR

| Sl. No | Description | Technical Parameters |
|---|---|---|
| 1 | Switchboard | |
| 2 | Manufacturer's Name | By Bidder |
| 3 | Type | By Bidder |
| 4 | Standards Followed | IEC 62271-100/200 |
| 5 | Main Bus bar | |
| | a) Current Rating | 630A |
| | b) Material | CU |
| | c) Grade | Electrolytic Cu |

| | | |
|---|---|---|
| | d) Whether Joints are Silver Plated | N.A |
| | e) Thickness of Coating | N.A |
| 6 | Earth Bus bar | |
| | a) Current Rating | 25kA |
| | b) Material | CU |
| | c) Grade | Electrolytic Cu |
| | d) Whether Joints are Silver Plated | N.A |
| | e) Thickness of Coating | N.A |
| 7 | Continuous current Rating for Ambient Condition of site when installed in IP 4X Switch board | |
| | a) Main Bus bar at Ambient Specified | 630A |
| | b) Tappings at Ambient Specified | 630A |
| 8 | Temperature rise of Bus bars while | |
| | a) Carrying rated Current and Installed in IP4X enclosure at an Ambient Temp specified. | As per IEC-60694 Table-V, IS-12729-2004 |
| | b) Under Short Circuit Condition | N.A |
| | Degree of Protection of Enclosure | SF6 gas chamber-Stainless Steel IP65<br>Drive-IP2X<br>Low Voltage-IP3X |
| 9 | Minimum Clearance in Air | |
| | a) Between Phases | Since all parts in SF6, clearance is not applicable. |
| | b) Between Phase to Earth | Since all parts in SF6, clearance is not applicable. |
| 10 | Clearance required at the Back & Front of Panel | AFR: 500 mm @ rear<br>1700 mm @ front |
| 11 | Overall Dimension of the Switch Board (mm) | |
| | a) Length | In line with Switch Board Configuration |
| | b) Width | 450m/ 600mm |

| | | |
|---|---|---|
| | c) Depth | 1400mm |
| | d) Height | 2400/2800mm |
| 12 | a) Access Height (mm) | |
| | i) Maximum | 1850 mm height of lock of LV box door |
| | ii) Minimum | 830 mm height of cable box handle |
| | b) Weight of Panel Board (kg) | |
| | j) Maximum : | Approx. 900 |
| | k) Minimum : | Approx. 700 |
| 13 | Insulation Level including all the Components | |
| | a) Power frequency withstand Voltage for 1 min | 28 kV |
| | b) 1.2/50 µ sec Impulse Withstand Level | 75 kV |
| 14 | Circuit Breakers | |
| (i) | Manufacturer's Name | |
| (ii) | Type | |
| (iii) | Manufacturer's Type reference | |
| (iv) | Closing Mechanism | Spring |
| (v) | Normal Current rating in Air & corresponding | 630A |
| (vi) | Ambient Temperature | 40°C |
| (vii) | Derating factor for Ambient condition at Site | N.A |
| (viii) | Service Voltage & Frequency | 11 kV, 50 Hz |
| (ix) | Maximum Voltage at which CB can Operate continuously | 12 kV |
| (x) | Rated Making Capacity | 25kA |
| (xi) | Rated Breaking Capacity | 63kAp |
| (xii) | a) Symmetrical | 25kA |
| (xiii) | b) Asymmetrical | 27kA |
| (xiv) | Short Circuit With stand Capacity | |
| | a) 3 Sec | 25kA |

| | | |
|---|---|---|
| | b) 1 Sec | 25kA |
| (xv) | Total Make time | Within 60ms |
| (xvi) | Total Break time | Within 60ms |
| (xvii) | No. of Breaks per pole | 1 No. |
| (xviii) | Total Length of Break per pole | |
| (xix) | No. of Auxiliary Contacts (NO/NC) for Employer's use | 8 |
| (xx) | Type of Arc Control Device | Vacuum |
| (xxi) | Arc Duration time | |
| | a) 100 % Load Current | Within 10ms |
| | b) 10 % Load Current | Within 10ms |
| (xxii) | Spring Charging Motor | |
| | a) Type | Universal Motor |
| | b) Voltage | 230 V AC |
| | c) Rating in kW | 0.223 |
| | d) Protection relay provided | Not Applicable |
| | e) Protective MCB s provided | Yes |
| (xxiii) | Power required for : | |
| | a) Closing | |
| | i) Momentary | 250W |
| | b) Holding | N.A |
| | c) Tripping | 250W |
| | d) Time taken for Charging Motor to Charge Spring completely | 8 seconds |
| (xxiv) | Number of consecutive operation the breaker can withstand and the recommended interval between these operations: | O-0.3Sec-CO-3Min-CO |
| (xxv) | Number of short circuit current interruption after which the breaker requires attention & maintenance | 100 @ 25 kA STC |
| (xxvi) | Number of normal operations after which the breaker requires attention & Maintenance | 10000 |
| (xxvii) | Rated capacitor breaking current of breaker/ contactor of each rating | N.A |
| (xxviii) | Confirm that trip and closing coils will be suitable for 110 V DC and the spring charging motor will be suitable for 240 V | Yes |

| | | |
|---|---|---|
| | AC | |
| (xix) | Maximum number of XLPE cables & sizes that can be terminated safely in the cable chamber without extension panel | |
| | a) Single core (Size & No. of Runs) | N.A |
| | b) Three core (Size & No. of Runs) | Max. 1 cables XLPE Three core 400 sq.mm |
| (xx) | Maximum no of cables that can be terminated in the cable extension box (Please state the dimensions of such cable extension Box) | N.A |
| (xxi) | Minimum available distance from the bottom of the panel to the terminals in cable box/chamber for terminating cables | 500mm. |
| (xxii) | Weight of circuit breaker and truck | fixed mounted GIS |
| 15 | Instrument Transformers | |
| (i) | Makes | |
| | a) CTs | By Bidder |
| | b) PTs | By Bidder |
| (ii) | Standards followed | IEC |
| (iii) | Confirm that CTs and PTs will be epoxy resin cast insulated | CT foil, VT metal-cast resin |
| (iv) | 3 second short time current rating of CTs, kA. | 25kA |
| (v) | 1 second short time current rating of CTs, kA. : | 25kA |
| (vi) | Dynamic current rating of CTs, kA : | 63kAp |
| (vii) | Confirm that accuracy classes shall be as specified and ratios and capacities shall be as required | Pls. refer Technical Offer |
| (viii) | Confirm that all protective, metering, control and annunciation devices, transducers as specified shall be provided | Pls. refer Technical Offer |
| (ix) | Enclose technical particulars, data sheets, catalogues of all types of relays and other plant being offered by you | Pls. refer Technical Offer |
| 16 | IP Rating | |
| | (a) Tank | IP 67 HV part |
| | (b) Cubicle assembly | IP 3X |
| 17 | SF6 Gas Pressure | 0.6 bar (0.06 MPA) |
| 18 | Gas Leakage Rate | < 0,1% per year |

| | | |
|---|---|---|
| 19 | Gas handling Requirement at Site | No Gas handling allowed at site |
| 20 | Cable Terminations | |
| | Make | By Bidder |
| | Type | Outer Cone |

### 7.2.3 Transformer

**A. 33/11 kV Transformers**

a) The transformer shall be installed in the way that no vibration will be transmitted to the building/ construction. The Transformer shall be of _____ kVA, 33/11 kV, oil filled type for normal application.

b) Requirement for two winding transformers with On Load Tap Changing Mechanism: -

The two winding Power transformers shall be Natural Ester oil immersed transformers shall conform to IS 2026, IS-1180 and IEC 62770 standard for Natural Ester Oil filled trans

c) This specification covers design, engineering, manufacture; shop testing, inspection, painting, packing, and supply of Distribution Transformers complete with all accessories for efficient and trouble-free operation of the proposed Substation.

d) The design, manufacture and performance of equipment shall comply with all currently applicable statutory regulations, and safety codes in the locality where the equipment will be installed. Nothing in this specification shall be construed to relieve the E & M Concessionaire of this responsibility. The Quality of Raw material, Manufacturing process & design parameters should meet the requirement so as to ensure quality of transformers former and shall have following specifications:

- The equipment shall conform to the latest edition of applicable standards as follows. In case of conflict between applicable standards and this specification, this specification shall govern.

o IS 2026, for Tests & tolerance on Guaranteed Particulars

o IS:3639 for Fittings and Accessories

o IS:2099 for Bushings > 1000 V

o IS:7421 for Bushings < 1000 V

o IS:1271 for Electrical Insulation classified by Thermal stability

- Transformers shall accept, without injurious heating, combined voltage and frequency fluctuations which produce the 125% over fluxing condition for one minute.

**1. GENERAL CONSTRUCTION: -**

All material used shall be of best quality and of the class most suitable for working under the conditions specified and shall withstand the variations of temperature and atmospheric conditions, overloads, over excitation, short-circuits as per specified standards, without distortion or deterioration or the setting up of undue stresses in any part, and also without affecting the strength and suitability of the various parts for the work which they have to perform.

**a) Tank:**

The exterior of tank and other steel surfaces exposed to the weather shall be thoroughly cleaned and have a priming coat of zinc chromate applied. The second coat shall be of an oil and weather-resistant nature, preferably of distinct colour from the prime and finish coats. The final coat shall be of a flossy, oil and weather resisting non-fading paint of specified shade. The interior of the tank shall be cleaned by shot blasting and painting with two coats of heat resistant and oil insoluble paint.

i. Steel bolts and nuts exposed to the atmosphere shall be galvanized.

ii. Unless otherwise stated, the tank together with radiators, conservator, bushings, and other fittings shall be designed to withstand without permanent distortion the following conditions:

iii. Full vacuum of 760 mm of Hg, for filling with oil by vacuum.

iv. Internal gas pressure of 0.35 Kg/cm2 (5 lbs/sq.in) with oil at operating level.

v. The tank cover shall be suitably sloped so that it does not retain rainwater.

vi. The material used for gaskets shall be cork neoprene or approved equivalent

**b) Core:**

Transformer shall be double wound, core type with low loss, non-ageing, high permeability PRIME GRADE, CRGO with M4 Grade or Better, perfectly insulated and clamped to minimize noise and vibrations. Followings should be Mandatory for any Manufacturer: -

i. Transformer shall be of BOLTLESS core design

ii. Core shall be purchased Directly from Manufacturer or from their accredited Marketing organization of Repute & not through any agent. Bidder has to submit manufacturer's name during bidding having sufficient credential & Core has to be purchased from the approved manufacturer.

iii. Stage inspection of the core shall be done at manufacturer's premises & inspection call shall be given with following Documents:

- o Invoice of the supplier
- o Mill's test certificate
- o Packing list
- o Bill of landing & Bill of Entry certificate by customs

iv. Transformer manufacturer should have in-house core cutting facilities for proper control & monitoring of quality & to avoid mixing of Prime core with Second grade /defective core materials. Transformer Manufacturer should have inhouse slitting Machine so as, core is cut to width & stacked with minimum air gap thus ensuring Burr level less than 10Microns.

v. Core shall be procured from one of the reputed Manufacturers. The insulation structure for the core to bolts and core to clamp plates shall be such as to withstand a voltage of 2000V for one minute.

**c) Windings:**

i. Winding shall be made with 99.9% pure electrolytic grade copper, insulated with thermally upgraded paper (Insulation Class A / Conductor Interturn insulation Class E). The HV & LV winding should be able to withstand thermal and mechanical stress in the event of short circuit.

ii. Winding shall be carried in dust free area

iii. The completed core and coil assembly shall be dried in vacuum and shall be immediately impregnated with oil after the drying process to ensure elimination of air and moisture within the insulation.

**d) Oil**:

i. Transformer oil shall be as per IEC 62770 / IS-1180 - Natural Ester vegetable oil. Oil should be Environment friendly, Green & Biodegradable. It should also exhibit safety against fire hazards.

ii. Oil shall be filtered and tested for break down voltage (BDV) and moisture content before filling.

**2. TEMPERATURE INDICATOR: -**

One set of winding temperature indicators with necessary current transformer, heating coil and a detector element and one set of oil temperature indicator with maximum reading pointer shall be mounted locally so as to be readable at a standing height from ground level. Each of the above indicators shall be provided with necessary contacts for alarm and trip.

**3. TEMPERATURE RISE:**

a) The transformers shall be designed for continuous operation at their rated power without exceeding the temperature rise as per IS 2026 – Part 2 & it shall be 50˚C - 55˚C, over an ambient temperature of 45 ˚C. In core and other metallic parts: Temperature shall in no case reach a value that will damage the core itself, other parts or adjacent materials.

b) With the given climatic conditions, the transformers shall be capable of operating continuously on any tap at their normal rating without exceeding following temperature rises:

c) 70° C above ambient temperature for oil.

d) 80° C above ambient temperature for winding.

e) The temperature of a hot spot in winding shall not exceed 130°C when calculated over max. annual weighted average temperature of 35° C.

**4. BUCHHOLZ RELAY**

The Buchholz relay shall be provided with two floats and two pairs of electrically separate contacts for alarm and trip. The relay shall have facility for testing by injection of air by hand pump and with cock for draining and venting of air. The location of the relay shall be such that all rising gas will readily reach it.

**5. BUSHINGS**

a) All bushings shall be homogenous, solid porcelain oil commissioning type, uniformly glazed and free from blisters, burns and other defects and shall be furnished complete with suitable terminal connectors of adequate capacity. The bushings shall be located so as to provide necessary electrical clearances between phases and also between phase and ground as specified in relevant standards.

b) Bushings rated for 400A and above shall have non-ferrous flanges and hardware.

c) All bushings shall have puncture strength greater than the dry flashover value.

d) Neutral CTs shall be furnished with its secondary leads wired up to the terminal blocks. The terminals for CT secondary leads shall have provision for shorting. The arrangement shall be such that the CT can be removed from the transformer without removing the tank cover.

The minimum phase-to-phase and phase-to-earth external clearances for LV & HV bushings shall be as per IS 1180 (part-2)

**External (Air) clearances between bushings mounted on transformers:**

| Nominal System Voltage | Phase to Phase clearance in mm | Phase to Earth clearance in mm |
|---|---|---|
| Up to 1.1 kV | 75 | 40 |
| 11 kV | 255 | 140 |
| 22 kV | 330 | 230 |
| 33 kV | 350 | 320 |

**Air Clearances in Cable Box**

| Nominal System Voltage | Phase to Phase clearance in mm | Phase to Earth clearance in mm |
|---|---|---|
| Up to 1.1 kV | 25 | 20 |
| 11 kV | 130 | 80 |
| 22 kV | 240 | 140 |
| 33 kV | 350 | 220 |

**6. TERMINAL ARRANGEMNT**

a) Low voltage terminals of Power transformer shall be brought out to bushing inside Cable Box

b) High voltage terminals of Power transformer shall be in arrangement to connection of Cable inside cable box

c) The cable box shall be suitable for cable termination kits and shall be self-supporting, weatherproof, air-filled type, complete with all hardware such as gland plate, brass glands, tinned copper lugs, armour clamps etc.

**7. MARSHALLING BOX**

a) A sheet steel weatherproof marshalling box of IP 55 construction shall be mounted on the tank of transformer and shall accommodate all auxiliary devices except those which must be located directly on the transformer. All terminal blocks for external cable connections shall be located in this box. The terminal blocks shall be ELMEX 10 mm2 or approved equal.

b) The marshalling box shall have the following as a minimum:

i. Loads disconnect switch for incoming power supply for auxiliaries.

ii. All outgoing connections from transformer viz. Buchholz relay, temperature indicators, fault contacts for annunciation system etc.

iii. Wiring and termination points individually of the following trip contacts for remote alarm and trip.

- Winding temperature high / very high
- Oil temperature high / very high
- Buchholz relay Alarm / Trip
- Oil level low

c) Cubicle illumination lamp with door switch and space heater with thermostat and ON/OFF switch shall be provided.

d) Marshalling box shall be designed to facilitate external cable entry from bottom. Removable gland plates shall be furnished with double compression type brass cable glands.

e) Sufficient space shall be provided to avoid sharp bending and for easy connection of cables. A minimum space of 200 mm from the gland plate to the nearest terminal block shall be provided.

f) Wiring shall be done with HR PVC 650 V grade wires. The wire size for CT circuits shall be 4 mm2 copper and for other circuits shall be a minimum of 2.5 mm2 copper. Not more than two (2) wires shall be connected to a terminal. 10% spare terminals shall be provided.

g) All devices and terminal blocks within the marshalling box shall be identified by symbols corresponding to those used in applicable schematic or wiring diagrams.

**8. GROUNDING**

a) Two grounding pads, located on the opposite sides of the tank, shall be provided for connection of Switchyard ground mat for each transformer. Grounding pads shall have clean buffed surface with tapped holes. M10 G.I. bolts, nuts and spring washer shall be provided.

b) 2 Nos. Ground terminals each shall also be provided on marshalling box, cable box & OLTC panel to ensure effective earthing.

c) The Neutrals of the windings shall be brought out through neutral bushings at suitable location. The neutrals shall be suitable for connecting 75x10 mm Copper flat.

d) For conductivity of earth connection, all gasketed joints shall be provided with minimum two nos. of copper strip of adequate size.

**9. ON Load Tap Changing Mechanism**

a) Should be Separately mounted out tank type (CTR make)

b) Should comprise of 20 Steps / 21 Positions: +10% to -15% @ 1.25%

c) RTCC & AVR to be supplied along with the OLTC.

d) OLTC shall be as per following:

i. The OLTC gear shall be designed to complete successfully tap changes for the maximum current to which transformer can be loaded i.e. 150% of the rated current. Devices shall be incorporated to prevent tap change when the through

current is in excess of the safe current that the tap changer can handle. The OLTC gear shall withstand through fault currents without injury.

ii. When a tap change has been commenced it shall be completely independently of the operation of the control relays and switches. Necessary safeguard shall be provided to allow for failure of auxiliary power supply or any other contingency which may result in the tap changer movement not being completed once it is commenced.

iii. Oil in compartments which contain the making and breaking contacts of the OLTC shall not mix with oil in other compartments of the OLTC or with transformer oil. Gases released from these compartments shall be conveyed by a pipe to a separate oil conservator or to a segregated compartment within the main transformer conservator. An Oil surge relay shall be installed in the above pipe. The conservator shall be provided with a prismatic oil level gauge.

iv. Oil, in compartments of OLTC which do not contain the make and break contacts, shall be maintained under conservator head by valve pipe connections. Any gas leaving these compartments shall pass through the Buchholz relay before entering the conservator.

v. Oil filled compartments shall be provided with filling plug, drain valve with plug, air release vent, oil sampling device, inspection opening with gasketed and bolted cover with lifting handles.

e) OLTC driving mechanism and its associated control equipment (local) shall be mounted in an outdoor, weatherproof cabinet with IP 55 protection which shall Include: -

i. Driving motor (433V, 3-phase, 50 Hz. AC squirrel cage).

ii. Motor starting contactor with Motor Protection Circuit Breaker, isolating switch and HRC fuses.

iii. Control switch: Raise/off/lower (spring return to normal type).

iv. Remote/local selector switch (maintained contact type).

v. Mechanical tap position indicator showing rated tap voltage against each position and resettable maximum and minimum indicators.

vi. Limit switches to prevent motor over-travel in either direction and final mechanical stops.

vii. Brake or clutch to permit only one tap change at a time on manual operation.

viii. Emergency manual operating device (hand crank or hand wheel).

ix. A five-digit operation counter.

x. Electrically interlocked reversing contactors (preferably also mechanically interlocked).

xi. 240V, 50 Hz. AC space heater with switch and HRC fuses.

xii. Interior lighting fixture with lamp door switch and HRC fuses.

xiii. Gasketed and hinged door with locking arrangement.

xiv. Terminal blocks, internal wiring, earthing terminals and cable glands for power and control cables.

xv. Necessary relays, contactors, current transformers etc.

f) Control requirements for OLTC: The following electrical control features shall be provided:

i. Positive completion of load current transfer, once a tap change has been initiated, without stopping on any intermediate position, even in case of failure of external power supply.

ii. Only one tap change from each tap change impulse even if the control switches or push button is maintained in the operated position.

iii. Cut-off of electrical control when manual control is resorted to. Cut-off of a counter impulse for a reverse tap change until the mechanism comes to rest and resets the circuits for a fresh operation.

iv. Cut-off of electrical control when it tends to operate the tap beyond its extreme position.

g) Automatic Control of OLTC: Automatic OLTC control shall include the following items:

i. Voltage setting device.

ii. Voltage sensing and voltage regulating devices.

iii. Line drop compensator with adjustable R and X elements.

iv. Voltage setting device.

v. Voltage sensing and voltage regulating devices.

vi. Line drop compensator with adjustable R and X elements.

vii. Timer 5-25 seconds for delaying the operation of the tap changer in the first step for every tap change operation.

viii. Adjustable dead band for voltage variation.

**10. OLTC Panel:**

a) The OLTC remote control equipment shall be suitable for 30V DC supply and shall be housed in an indoor sheet cubicle to be located in a remote-control room. The OLTC control panel shall comprise of rigid welded structural frames made of structural steel section or of pressed and formed cold rolled steel and frame enclosures, doors and partitions shall be of cold rolled steel of thickness 2 mm. Stiffeners shall be provided wherever necessary. All doors, removable covers and plate shall be gasketed all around with neoprene gaskets. Panel shall be dust, weather and vermin proof providing degree of protection of IP54, colour of finish shade for interior and exterior shall be Powder Coated RAL7032 respectively. Earthing bus shall be of 25 x 6 mm copper.

- Control switch: Raise/ Off/ Lower (spring return to normal type)
- Auto/manual selector switch: (Maintained contact type)

b) Tap Position indicator:

i. Facia type alarm annunciator with “accept” and “lamp test” facilities.

- A.C. supply failure
- Drive motor auto tripped
- Tap change delayed

ii. Necessary auxiliary relays

iii. Lamp indications for:

- Tap change in progress
- Lower limit reached
- Upper Limit reached
- Cable glands for power and control cables
- 240 V rated panel space heater with ON-OFF switch
- Fluorescent type interior lighting fixture with lamp and door switch
- HRC fuses
- Terminal blocks
- Internal wiring
- Earthing terminal
- Supply ON Indication Lamp.
- Labels for Accessories.
- Automatic Voltage Regulating Relay.
- Heater Switch (Rotary Type)
- Control Supply Switch (Rotary Type)
- Hooter for Facia annunciator (230V AC)
- Time Delay Relay for ‘Tap Change Delayed’ (110V AC)
- H.V. Voltmeter (Digital Type)

- H.V. Voltmeter Selector Switch (Rotary Type)
- L.V. Voltmeter (Digital Type)
- L.V. Voltmeter Selector Switch (Rotary Type)
- PT for AVR.
- Tap changer Counter for registering

**11. Valves**

a) Valves shall be of forged carbon steel above 50 mm and of gun metal for sizes upto 50mm. They shall be of full way type with screwed ends. They shall be opened by turning counter clock-wise when facing the hand wheel. There shall be no oil leakage when the valves are in closed position.

b) Every valve shall be provided with open/close position indicators. The valves shall be suitable for pad locking in open/close positions. All screwed valves shall be furnished with pipe plugs for protection.

c) All valves shall be provided with flanges having machined faces drilled to suit the applicable requirements.

d) Oil tight blank flanges shall be provided for the following.

e) valves opening to atmosphere.

f) for each connection for use when any radiator is detached.

g) Any special radiator valves tools required shall be supplied by the bidder.

h) The Transformer shall provide with Nitrogen Fire Protection system so as to envisage complete safety from Fire Hazards

**12. TESTS:**

The tests listed below shall be carried out and shall be deemed to be included in the BIDDERS scope. E & M offer shall include prices for carrying out all tests as specified.

**a) ROUTINE TESTS – The manufacturer should have NABL accredited test lab.**

i. Measurement of winding resistance

ii. Measurement of voltage ratio and check of voltage vector relationship

iii. Measurement of impedance of voltage (principal tapping), short circuit impedance and load loss.

iv. Measurement of no-load loss and current

v. Separate source voltage withstand test

vi. Induced overvoltage withstands test (2 times the rated voltage)

vii. 2kV withstand test for all wiring

viii. Magnetic Balance Test

**b) TYPE TESTS**

i. Pressure & Vacuum test needs to carry out on 1unit of each rating

ii. Noise level test needs to carry out on 1 unit of each rating.

iii. Heat run and Impulse test shall be carried out on 1 unit of each rating…

iv. Short circuit report of similar / higher rating not older than 3 years

**c) ACCEPTANCE TESTS**

i. One transformer of each rating, selected randomly from the lot shall be sent for measurement of losses, declared by vendor (on data sheet) at third party / any NABL accredited lab.

ii. Oil Leakage test for acceptance shall be conducted at pressure of 0.35kg/sq.cm for one hour.

iii. Checking of weights, Dimensions, fitting and accessories, tank sheet thickness, oil quantity, material, finish and workmanship, Physical verification of core coil assembly and measurement of flux density on one unit of each rating of the offered lot with reference to the GTP and contract drawings.

iv. Temperature rise test on one transformer selected randomly to be sent at NABL accredited lab at Concessionaire cost. If transformer fails, the test or found to be under rated the contract shall be terminated as per clauses of contract agreement.

**13. LOSSES:**

Losses shall be as follows: -

a) Respective Current density & Flux Density shall be to suit the required No load & loss levels

b) All the measurement of losses shall be carried out by digital meters of class 0.5 or better accuracy and should be certified by the manufacturer. If the losses measured are found to be out of tolerance band as stated in Standard and guaranteed losses declared by manufacturer, the same shall be attributed to the manufacturer as per capitalization formula till the end of warranty period.

c) One transformer of each rating, selected randomly from the lot shall be sent for measurement of losses, client reserves rights of cancellation & replacing equipment of proper specification by E & M Concessionaire to comply as per contract agreement terms / condition

**B. 11/.433 kV Distribution Transformers**

1. SCOPE OF SUPPLY & SERVICES

The scope of work for the "Distribution Transformers" and associated items covered under this specification shall include but not limited to the following:

a) Design, engineering, procurement, manufacture, fabrication, shop testing and inspection, supply, packing and forwarding, transportation to site, Unloading, Erection and Commissioning of Transformers.

b) All materials supplied under this contract shall be new and unused.

c) Inspection and expediting, handling, packing, forwarding, transporting, documentation including submission and approval of drawings, Commissioning, and performance testing of equipment.

d) Engineering of all the systems covered in this specification, including preparation and submission of detailed drawings & documents / calculations / reports as detailed and quantification of entire items included in scope.

e) Submission of drawings, documents, test certificates & calculations for information / approval of the PURCHASER / CONSULTANT, as elaborated elsewhere in this document, including those required for submission to Chief Electrical Inspector of Government.

2. System Design Basis

a) The insulation requirement of transformer windings shall be: -

| | | |
|---|---|---|
| Normal voltage (kV) | 0.433 | 11 |
| Highest system voltage kV (RMS) | 1.1 | 12 |
| Lightning impulse with stand voltage kV (peak) | - | 75 |
| Short duration power frequency withstands voltage kV (RMS) | 3 | 28 |

b) DUTY REQUIREMENT

i. The transformer and all its accessories like current transformers, bushings etc., shall be designed to withstand without injury, the thermal and mechanical effects of any external short circuit to earth and of short circuits at the terminals of any winding for a period of 2 seconds. Transformer shall be capable of withstanding thermal and mechanical stresses caused by symmetrical or asymmetrical faults on any winding.

ii. Source short circuit levels to be assumed for design with an operating time duration of 3 sec:

At 33 kV : 25 kA

At 11 kV : 25 kA

At 0.433 kV : 50 kA

iii. Transformer shall have mechanical and thermal capabilities for withstanding the short circuit current for the specified duration without any damages.

iv. All the transformers shall be designed for the following over fluxing withstand capability:

110% : Continuous

125% : 10 seconds for Distribution Transformer

v. The transformer shall be capable of being loaded in accordance with specified standards. There shall be no limitation imposed by bushings, tap-changer etc.

vi. The overload capacity of the transformer and their emergency short time ratings called for in schedule shall be furnished.

3. IMPEDANCE

The percentage impedance voltage at principal tapping on the ratio primary /secondary MVA base shall be as per technical data. The impedance shall be without negative tolerance.

To achieve the above percentage impedance value, no reactor either inside or outside the tank shall be used.

4. LOSSES

i. Loss figures shall be guaranteed, without positive tolerance.

ii. The no load loss in kW at the rated voltage and frequency and the load loss in kW at the rated voltage, rated frequency, rated output and at 75 Deg. C shall be quoted and these figures shall be guaranteed.

iii. If the test figures exceed the quoted values, the transformer will be rejected.

iv. The transformers shall be installed in that way, that no vibrations will be transmitted to the building / construction. The connecting of the 11 kV-cables at the transformers only shall occur with right-angle connectors. Those right-angle connectors shall be calculated into the price of the 11 kV-cable.

**C. DRY TYPE 11 / 0.433 KV TRANSFORMER (INDOOR PORTAL / NICHES SUBSTATION)**

1. SPECIFIC REQUIREMENTS FOR DRY TYPE TRANSFORMERS

a) Temperature rise of winding measured by Resistance: 90 deg C

b) Constructional Features

i. The transformer shall be of cast resin encapsulate type, but shall be naturally cooled (AN) and moisture proof. Insulating materials used in construction shall be of non-inflammable. The transformer shall be housed in enclosure fabricated from sheet steel of minimum 2mm thick. Degree of protection for the enclosure shall be at least IP33. Screen shall be perforated sheet steel type. Mesh size shall be such that lizards, rats etc. cannot enter inside the enclosure.

ii. The enclosure shall be adequately reinforced to ensure rigidity so as to permit transportation of transformer within enclosure. Base frame for moving the transformer shall be min. 4mm thick and shall be provided with bi-directional rollers/mounting skid.

iii. Double leaf access shall be provided with concealed hinge and neoprene gaskets for easy access to H.V. links and also for withdrawal of core and coil assembly if required.

iv. Enclosure shall be provided with lifting lug and grounding terminals. Further the enclosure door shall have provision of padlocking in door-closed position. The door should be easily but firmly lockable.

v. For all dry type transformers, following safety interlocks shall be provided:

- A safety interlock shall be provided to ensure that the enclosure door can be opened only when transformer is de-energized.
- Safety limit switches operated by door handle shall be provided for tripping HV & LV side breaker.

vi. Similarly, the outer surface shall also be cleaned of all scale and then the primary coat shall be applied, immediately after cleaning. The second coat shall be of epoxy paint of shade conforming to Siemens Grey – RAL 7032.

vii. Steel bolts if used, shall be parkerised. Terminal screws, studs, nuts and bolts shall be of non- ferrous material, threaded conforming to IS.

viii. All fasteners exposed to weather shall either be nonferrous/Heavy duty type CPF/ZPF or hot dip galvanized or electroplated conforming to relevant I.S.

**2.** Core

a) Core, its supporting steel and insulation shall be of such design, material and construction that harmful changes in electrical or physical properties shall not occur during the life of transformer. Limbs and yoke shall have similar section to minimize effects of transverse flux. Butt joints between yoke and limbs shall not be made. Generous cooling ducts shall be provided for core heat dissipation to ensure that maximum temp. Rise will not exceed the temperature indicated in the technical data sheet.

b) Core and winding shall be strongly braced, casted and held at respective places to prevent displacement or distortion during transportation or abnormal electrical conditions in service. Core grounding arrangement shall be located at the top for easy access from inspection hole.

**3.** Windings

a) Each coil shall be high quality fibre glass insulated reinforced with epoxy resin, continuous smooth, high grade, electrolytic copper conductor, without sharp corners or bends and shall be adequately transposed to minimize eddy current losses and equalize current and temperature distribution. Abrasive damage and high dielectric stresses in insulation shall not occur. Similar coils shall be interchangeable. Liberal ducts shall be provided for prevention of 'hot spots' that may affect insulation life. Insulation of windings and other live parts should be adequate to sustain 110% of rated operating voltage continuously.

b) Coil supports shall be by permanently secured, highly compressed and dried regularly spaced insulating spacers. Coil clamping rings, if of steel shall each be earthed by connection to core clamping structure and shall otherwise be of insulating material built up from flat laminations.

c) Insulating material shall be of proven design. The insulating material shall be glass fibre reinforced conforming to class `F'. Coils shall be so insulated that impulse and power frequency voltage stresses are minimum and are suitable to withstand even the severest to temperature variation. Separate encapsulation for HV and LV winding shall be provided.

d) Winding assembly shall be dried in vacuum, thoroughly shrunk to final dimensions and resin casted. The whole assembly shall finally be held under compression of at least twice the thrust likely to be set up under a terminal short circuit.

e) Design, arrangement, insulation and assembly of the winding on core shall be so as to ensure uniform distribution of voltage surges amongst all coils and minimize stresses in winding due to terminal short circuit. No corona discharge shall result in the winding upon exciting the transformer for specified induced voltage test.

f) Earthing Arrangements: - The core coil assembly shall be directly connected to this ground bus by removable bolted link for effective grounding. Earthing terminals shall also be provided on cable box and marshalling box to ensure its effective earthing.

g) Terminal Arrangement

**i.** Terminal box shall be of air-filled type. The cable box shall have all standard facilities envisaged for dry type transformer.

ii. Cable boxes shall be designed to accommodate all cable joint fittings or sealing ends as required. The bottom plate shall be of non-magnetic stainless steel, brass or aluminium for all transformers on LV side requiring cable connections. The disconnecting chamber shall be air insulated, removable links and removable covers shall be provided for the disconnecting chamber. Plates through which high current carrying conductors pass, shall be of non-magnetic materials.

h) Off-Circuit Tap Changer

i. The off-circuit tap changing will be effected by change of links for dry type transformers. Arrangement shall be such that the contacts are correctly engaged. A warning plate indicating that change of links for tap changer switch shall be operated only when the transformer is de - energized shall be provided.

ii. All contacts shall be silver plated and held in position under strong contact pressure to ensure low contact drop and avoid pitting.

iii. The design of tap changing link for dry type transformers shall be such as to ensure that same tap is set on the three phase at a time.

i) Bushings / Support Insulators: -

i. Bushings/Support Insulators shall be designed and tested to comply with the applicable standards.

ii. Bushings shall have non- ferrous and non-magnetic flanges and hardware.

iii. Fittings made of steel or malleable iron shall be galvanised.

iv. All bushings/support insulators shall be supplied with terminal connector clamp suitable for supporting the bushing terminal & the PURCHASER'S conductor as specified in data sheet.

v. Minimum air clearance and minimum creepage distances shall be as per data sheet.

vi. Bushing/support insulators material shall be porcelain.

j) Temperature indicator: - Three numbers of programmable winding temperature indicator of digital type shall be provided. The Temperature indicator shall have a separate relay with 2 NO and 2 NC contacts for alarm and trip. The display shall be with LED type.

k) Marshalling Box

i. Sheet steel vermin and weather proof marshalling box, shall be provided with a controlled metal clad heater to accommodate the following equipment.

ii. Terminal boards and gland plates shall be with suitable glands for incoming and outgoing cables, meant for temperature alarm / trip, annunciation and lamp indication devices for remote panel, etc.

4. TECHNICAL DATA SHEET / PARTICULARS

TO BE SUBMITTED WITH TECHNICAL BID – SCHEDULE – TECHNICAL PARTICULARS

D. **DOCUMENTS TO BE SUBMITTED AFTER AWARD OF CONTRAC**T

i. General outline drawing, showing front elevations and plan views of the transformer and all accessories and external features with detailed dimensions, weights, crane lift for un tanking and for erection / removal of bushings, size of lifting lugs and pulling eyes, HV and LV terminal clearances, live terminal to ground clearance, quantity of insulating oil and dimensional details for foundation.

ii. Terminal box drawings showing disconnection chambers / LT busduct flange.

iii. Assembly drawings of HV, LV and Neutral groundings.

iv. Core earthing details with disconnecting link

v. Detailed calculation for radiator design and cooling fan capacity

vi. Schematic control and wiring drawing and drawings showing temperature indicator circuits and control system for cooling equipment.

vii. Drawing showing construction and mounting details of marshalling box.

viii. Drawing, giving details of name plate, terminal marking and connection diagram.

ix. Drawing on tap changer gear assembly and online OLTC oil filtration system.

x. The magnetisation characteristic curves of the bushing current transformers, indicating the knee point voltage excitation current and secondary resistance.

xi. Drawing on terminal clamps.

xii. Core saturation curves.

xiii. Calculation to demonstrate the ability of transformer to withstand dynamic forces due to short circuit.

xiv. Detailed erection, testing & commissioning, operation and maintenance manuals.

xv. Detailed Instruction for storage of equipment at site.

xvi. GA, Dimensions & Weight of Transformer during shipment.

xvii. Any approval given to the detailed drawings by the PURCHASER shall not relieve the SUPPLIER of the responsibility for the correctness of the design, completeness of the equipment supplied and in the execution of the works in accordance with the terms of specification.

xviii. Additionally, eight (8) sets hard copies of above drawing shall be submitted by the SUPPLIER for Client's approval purpose.

## E. TESTING & INSPECTION

### 1) INSPECTION

a) The accredited representative of the PURCHASER shall have access to the SUB-SUPPLIER's works at any time during working hours for the purpose of inspection of manufacture or testing and selection of samples of the materials going into the equipment. The SUPPLIER shall provide necessary facilities for such inspection or test.

b) The core and coil assembly shall be offered for PURCHASER's /CONSULANT's inspection prior to tanking and the readiness for such inspection shall be intimated at least 15 days in advance. The tanking of core and coil assembly shall be taken up only after approval by PURCHASER /CONSULTANT.

c) All the type / special / routine tests on the transformers as per of latest issue and indicated below will be witnessed by PURCHASER's / CONSULTANT's Engineers and all necessary facilities for inspection and testing shall be provided by the SUPPLIER. The transformer shall be completely assembled and tested at the SUPPLIER's factory.

d) The SUPPLIER shall ensure that the test instruments have calibration certificate issued by an approved standard laboratory, not earlier than six months from the date of testing.

e) The readiness of the transformers for testing and final inspection shall be intimated to the PURCHASER / CONSULTANT at least 15 days in advancefor deputing Engineers for inspection / witnessing the tests. The transformer

f) will be accepted at site by the PURCHASER's / CONSULTANT's Engineer only on production of the approved test certificates.

### 2) FACTORY ASSEMBLY AND TESTS

a) The following type tests (to be conducted on any one (1) of the Distribution transformers for each rating as per specified standards shall be carried out in the presence of representatives from PURCHASER / CONSULTANT. The PURCHASER shall have the right to test the transformer at neutral agency or test the transformer at SUPPLIER's works through external agency:

Temperature rise test at the barest tap position at ONAN (Loss figures at corresponding tapping to be considered, for testing).

b) The following routine tests as per specified standards shall also be carried out on the all types of transformers, free of cost.

i. Measurement of winding resistance.

ii. Measurement of voltage ratio and check of voltage vector relationship,

iii. Measurement of impedance voltage / short circuit impedance (principal tapping) and load loss.

iv. Measurement of no-load loss and current.

v. Measurement of insulation resistance.

vi. Dielectric tests (Power frequency voltage test and induced over voltage withstand test).

vii. Oil leakage test on transformer tank: The tank and oil filled compartments shall be tested for oil tightness by completely filling with air / oil of viscosity not greater than that of insulating oil, conforming to specified standards at the ambient temperature and applying a pressure, equal to the normal pressure plus 35 kN/Sq.m measured at the base of the tank. This pressure shall be maintained for a period of not less than 12 hours for oil and one hour for air during which time no leakage shall occur.

viii. Magnetic balancing test.

ix. Measurement of no-load current with 415 volts supply.

x. Check for polarity and ratio tests for knee point voltage and magnetising current for bushing current transformer.

xi. Measurement of zero sequence impedance.

xii. Measurement of harmonics of the no load current.

xiii. Measurement of tank and capacitance of each winding to earth (with all other windings earthed) and between all windings (connect together) to earth.

c) The test sequence shall be tests on transformer tank, heat run test, pressure test on the assembled transformer, routine tests and special tests.

**3) TESTS AT SITE**

a) After erection at site, the transformers shall be subjected to the following tests by the CONCESSIONAIRE, who will be engaged by the PURCHASER:

i. Insulation resistance test.

ii. Ratio and polarity test on all taps.

iii. Dielectric test on oil

iv. Open circuit and short circuit test

v. Operation test of OLTC

vi. Operation test of protection devices and interlocks.

b) Measurement of winding resistance at all taps.

c) Any other test as may be insisted upon by PURCHASER / CONSULTANT.

**4) TEST CERTIFICATES**

a) Six copies of the test certificates on the above type tests / special tests / routine tests with the endorsement of the Inspecting Officer shall be furnished for approval.

b) The test report shall provide the following information:

i. Complete identification data, including serial no. of the transformer.

ii. Method of application where applied, duration, and interpretation of results in each test.

iii. Temperature data corrected to 75 deg. C including ambient temperature.

c) The equipment will be rejected if test results are not in conformity with the Guaranteed Technical particulars.

d) Besides the above test certificates, SUPPLIER / SUB-SUPPLIER's test certificates in respect of the following accessories shall also be furnished in six copies:

i. Off-circuit tap changer

ii. Bushings

iii. Bushing current transformers (with magnetisation characteristic curves)

iv. Buchholz relays & Surge relay

v. Magnetic oil level gauge

vi. Winding temperature controller.

vii. Oil temperature controller

viii. Radiators

ix. Transformer oil

x. Any other bought out components not specifically mentioned herein.

e) The SUPPLIER shall also furnish test certificates to the effect that the transformer core has been tested after assembly and immediately prior to the despatch of the transformer for one minute at 2000 volts AC between all bolts, side plates and structural work.

**TABLE 6: TECHNICAL DATASHEET FOR OIL IMMERSED TYPE 33/11KV TRANSFORMER**

| | |
|---|---|
| Rated power | _____KVA as specified / as required |
| Voltage (primary side) | 33 kV |
| Voltage (secondary side) | 11 kV |
| Nominal Frequency | 50 Hz |
| Cooling | ONAN |
| Tapping | 20 steps (+10% to -15% @ 1.25%) |
| Internal gas pressure | 0.35 Kg/cm2 (5 lbs/sq.in) |
| Core design | Boltless |
| Oil | Natural ester vegetable oil as per IEC 62770, IS-1180 |
| Winding insulation | Thermally upgraded paper (Insulation class-A / conductor Inter turn insulation class-E) |
| Impedance voltage | 7.0% |
| Vector Group | Dyn11 |
| Location | Grid station |
| Primary connection | Totally insulated plug-in connector |
| Secondary connection | Connection safe to touch with connecting lug and insulating cover |

**TABLE 7: TECHNICAL DATASHEET FOR 11/0.433KV DISTRIBUTION TRANSFORMER AT PORTAL AND INSIDE TUNNEL**

| S. No. | Description | Technical Parameters |
|---|---|---|
| 1 | **GENERAL** | |
| | Application/designation | Distribution transformer |
| | Service | Step down transformer |
| | Type | Dry type cast resin / two winding |
| | Installation | Indoor |
| | Degree of protection for transformerswith enclosure as per IS:2147 | IP-33 |
| 2 | **RATINGS** | |
| | Rating | _____ KVA, _____KVA |

| S. No. | Description | Technical Parameters |
|---|---|---|
| | Rated primary voltage | 11000 V |
| | Rated no load secondary voltage | 433 V |
| | No. of phases | 3-phase on HV<br>3-phase with neutral on LV |
| | Frequency | 50 Hz |
| | Vector group | Dyn 11 |
| | Percentage impedance | 6.25%,5.0% |
| | Permissible tolerance on impedance | ± 10% |
| | System fault current for 1 secondduration | HV Wdg : 25 kA (rms)LV Wdg : 50 kA (rms) |
| | Type of cooling | Natural air cooling (AN) |
| 3 | **SYSTEM VOLTAGE** | |
| | Nominal system voltage | 11000 V |
| | Highest system voltage | 12 kV for 11 kV winding<br>1.1 kV for 433 V winding. |
| 4 | **NEUTRAL EARTHING** | |
| | Transformer neutral earthing | LV Winding: Effectively earthed<br>Note:-1) Additional neutral bushing should beprovided for neutral earthing.<br>Note: - 2) Neutral CT Shall be provided for REF Protection .CT Details shall be finalizedduring drawing approval stage. |
| 5 | **INSULATION WITHSTAND VOLTAGE** | |
| | Impulse (1.2/50 µ-sec. wave) | HV Winding : 75 kV peak for 11 kV winding |
| | One minute power frequency | HV Winding : 28 kV for 11 kV winding<br>LV Winding : 3.0 kV |
| | Class of Insulation | F |

| S. No. | Description | Technical Parameters |
|---|---|---|
| 6 | **TEMPERATURE** | |
| | Reference Ambient Temperature (Design) | -15% to 30°C |
| | Temperature rise by winding resistance at lowest tap (Max) | 90°C |
| | Temperature on enclosure by thermometer (Max) | 50°C |
| **7** | **Noise level** | |
| | Permissible noise level (Max) | 73 dB |
| 8 | **TAP CHANGING LINKS** | |
| | Taps required | Off-circuit full MVA rating at each tap |
| | Type | Bolted link (Tinned copper links) |
| | Tappings on windings | HV |
| | Total tapping range | ±7.5% |
| | Steps | 2.5% |
| | Parallel Operation | Momentary with similar transformer. |
| 9 | **BUSHINGS/SUPPORT** | |
| | Voltage class | a) HV line end - 11 kV<br>b) LV line end / LV neutral - 1.1 kV |
| | Impulse (1.2/50 µ-sec. wave) | HV Winding : 75 kV peak |
| | One minute power frequency | HV Winding : 28 kV<br>LV Winding / LV neutral : 3.0 kV |
| | Minimum creepage distance | 25 mm / kV |
| 10 | **SURGE DIVERTER** | 3 nos. of Polymeric Zinc Oxide surgeArrestors<br>( 10 kV , 10 kA , line discharge Class-2) |
| 11 | **MINIMUM CLEARANCE IN AIR** | |
| | HV phase to phase | 230 mm |
| | HV phase to earth | 180 mm |

| S. No. | Description | Technical Parameters |
|---|---|---|
| | LV phase to phase | 25.4 mm |
| | LV phase to earth | 25.4 mm |
| 12 | **TERMINAL CONNECTIONS** | |
| | HV line end terminal with HT cable box | Suitable for terminating 11 kV x 300sq.mm<br>XLPE armoured earthed grade cables. |
| | LV line end terminal with LT cablebox | Suitable for terminating 0.415 kV x 300sq.mm<br>XLPE armoured earthed grade cables. |
| | LV neutral bushing | LV neutral bushings as per specification |
| | PURCHASER's earthing | Two no's of 185 sq mm copper earth conductor |
| | Colour finish shade of enclosure Interior/ exterior<br>Cable/bus entry (bottom/Top side) | Glossy finished RAL 7032<br>Bottom for HTCables/Top for LT cables |
| 13 | **ENCLOSURE** | |
| | Details of enclosure material andthickness | As per specification |
| 14 | Orientation of HT and LT termination compartments. | 90 deg displacement |

### 7.2.4 Diesel Generator Sets

**1. Standards**

The design, material, construction, manufacture, inspection, testing and performance of the Engine/ Generator sets shall comply with all currently applicable standard, regulations and safety codes in the locality where the equipment shall be installed.

Standards to which the equipment covered in this tender shall be designed, manufactured, inspected and tested are listed below: -

- ISO – 3046 Parts 1 to 4
- BS – 4999 all parts including part 71 / equivalent standards.
- IEC Standards for electrical and electronic equipments.
- A.S.M.E. Boiler and pressure vessel code for welding procedures and welder Qualification for all diesel engine sub systems.
- TEMA Standards for tubular heat exchangers.

**2. Scope**

a) The specification covers Design, Manufacture and Testing at works of 2 Nos.2000 KVA, 11 KV Prime duty (No standby duty DG is recommended) Diesel Generator sets with associated accessories including Synchronizing Panel, Neutral Isolator / Neutral Grounding Resistor Panel.

b) The D.G. Sets are intended for use as emergency sets to start on AMF (Automatic Start on Mains Failure) and capable of a minimum of 50 - 60% step load and prime power continuous rating as per BS 5514 not less than their rated capacities at 0.8 PF. The speed of D.G. Sets shall not exceed 1500RPM and shall be of four-stroke design for operation on high-speed diesel.

c) The D.G. Sets with Radiator mounted on the skid, shall be capable of achieving 100% rated within 15 seconds of initialling a start& 10% overload for 1hr in every 12hours of operation. The D.G.Sets are intended for operating in parallel with provision for auto synchronizing and auto load sharing. The offer for the D.G. Sets shall include well designed ventilation and fuel systems, startup batteries with associated chargers, interconnecting piping, system and protection earthling with neutral grounding resistor and isolating facility, local control & AMF, 11 KV DG switchgear, cabling to the switchgear and necessary gadgets for interfacing to Tunnel management system (SCADA) to make the generating system complete in all respects, including acoustic control to meet statutory requirements.

d) The scope of services include delivery at site, positioning on foundation (Civil works will be done by some other agency), erection, testing & commissioning of DG sets with associated 11KV switchgear, running of DG sets on full loads, performance testing of the complete system to prove guaranteed parameters for fuel oil consumption, acoustics and temperature rise, including but not limited to the following.

i. Supply, installation, testing and commissioning of 11KV D.G.Sets Radiator mounted on Skid

ii. Silencers, Exhaust piping including the outlets, insulation up to chimney.

iii. Earthing system (system earthing & protection earthing) with earthing resistor.

iv. Heavy duty antivibration spring type movement for the DG sets including hardware.

v. Pipe lines from Bulk fuel storage tank to intermediate tank, day tanks and spill tank with associated pumps, valves, including necessary level sensors /over flow controls, float valve in each day tank complete with support structures and civil works.

vi. Brush less exciter and voltage regulators

vii. Generator Lubrication systems including pumps, piping, oil coolers, oil filters and reservoir.

viii. RTDs, BTDs and Space Heaters in Alternator (Anti condensation Type) Exhaust Silencers (Residential Type) with Insulation.

ix. AMF and engine instruments and control panel comprising electronic governor, automatic voltage regulator, facility for auto synchronizing, auto-load and VAR sharing, basic minimum engine protection & annunciation, auto synchronizing and breaker control switch.

x. Power DB for auxiliaries, with necessary accessories and interlocks.

xi. DC power supply through adequately rated DC Battery and panel mounted Battery Charger.

xii. Ventilation system as / if required to maintain the temperature of the DG room within 10 degree C + ambient, with all DG sets running continuously.

xiii. Supply and installation of free standing Chimney to connect the Generators.

xiv. Fuel required for load test shall be included.

xv. Post Load testing 990Lts of Diesel need to be filled prior to Handing over.

xvi. All necessary consumables such as Diesel, Oil, Coolant, D.M.Water need to be in Vendors Scope.

xvii. Load Testing 2Hrs.30mins 100% ie.rated kVA capacities need to be performed at Site independently.

xviii. Synch of 4x2000kVA need to be performed and exhibited with 50% load sharing At site.

xix. Each D.G.Sets need to be load tested at 25%- 30mins, 50%- 30mins, 75%- 30mins, 100%-30mins, 110%- 30mins prior to Synch between both the D.G.Sets.

xx. Post Synch all the D.G.Sets need to run for 1hour in synch mode.

xxi. Preparation of shop drawings and getting approval, arranging inspection and obtaining safety certificate from the Electrical Inspectorate

xxii. Submission of wiring diagram, operation, maintenance and installation manuals, Test Certificates, Technical Leaflets etc.,

xxiii. The offer shall include necessary start up spares, fuel and lube oil required for commissioning and trial running of sets until handover.

xxiv. Generator Neutral Isolator Panel with Neutral Grounding Resistor connected to earth pit (S) through separate cables.

xxv. Laying of 11KV 3C Ar Aluminium XLPE Cable from Generator to the incoming terminal of the 11KV HT VCB DG Control Panel and to the NIS/NGR Panel.

xxvi. Terminal box on Generator AMF / Control panel, generator, 11KV VCB Panel & PLC panel with inter connections through control, instrument cables,

xxvii. Terminal box for SCADA interface (cabling to SCADA by other agencies)

xxviii. PLC panel (Separate or part of relay – metering panel) with auxiliary connections through control / instrument cables to Generator/Engine, 11KV VCB Panel, to have auto load dependent start-stop arrangement.

xxix. Battery with charger,

xxx. Incoming pipes flanges from underground storage tank to intermediate tank.

xxxi. Protection earthing grid with connections to earth pits and to the body of generator/Engine, DG Aux switchgear, DCDB, PB stations etc.,

xxxii. DG Aux switchgear incoming terminals, outgoing terminals connected to fans, pump motors through power cables/control cables as applicable.

xxxiii. Emission Testing at site need to conducted during the Load Test by Approved Labs

**3. Services**

a) Obtaining approval of local CEIG with regards to layout, clearances and earthing drawings and permission for energizing the DG Sets.

b) After installation, exhaust gas sample shall be collected and tested in a laboratory to see the conformance with the emission norms laid by PCB for this engine rating. Necessary data shall be furnished to the customer and / or their agency who are liasioning with PCB for clearance.

c) Required parameters for foundation to be provided by the DG vendor. Erection, testing and commissioning of the DG sets including all items covered under the scope of supply.

d) Load test at site on each set shall be for a minimum period of four (2Hrs.30mins). Fuel oil and all other consumable required for the test shall be supplied by the Concessionaire.

e) Cleaning debris and scraps from DG premises equipment and auxiliaries on completion of the entire installation.

f) Minor touchup painting of the equipment under reference.

**4. Site Conditions**

| | |
|---|---|
| Reference Design ambient or Electrical equipment | 15 degree C to 30 deg C |
| Attitude | 900 above MSL |
| Relative Humidity | 55 to 85 % |
| Design Humidity | 100% |
| Environment | Moderate conditions. |
| Installation | DG sets indoor |

## 5. Requirements of Diesel Generator Units

### a) General

i. Standard Diesel Engine Alternator sets and auxiliary equipments are as indicated in the product information published by the Manufacturer. Engine Alternator sets shall be suitable for parallel operation in conjunction with paralleling switchgear provided by others.

ii. The engine power (KW) shall be sufficient to deliver full rated generator set KVA, when operated at rated rpm, equipped with all engine-mounted parasitic and external loads and operated at specified site conditions. The D.G.Set need to be for Prime Power operation as per IS3046.

iii. Engine Alternator sets shall meet IEEE emergency power requirement to start and be on line within 15 seconds of to feed the distribution loads.

iv. The Engine Alternator sets shall be assembled on a robust base by the Engine Alternator manufacturer. In addition, the supplier shall provide dimensions of a concrete foundation block to match the generator set base, sized to dampen effects of disturbing vibrating forces. The foundation shall be isolated from the building structure. The generator set base shall be designed and built by the Engine Alternator manufacturer to resist deflection, maintain alignment, and minimize resonant linear vibration.

v. Vibration isolators shall be of resilient rubber design and installed between the Engine Alternator set base and the mounting surface. The isolators shall bolt to the Engine Alternator set base and foundation block. The pads shall be resistant to heat and aging, and antifreeze, diesel fuel, and cleaning compounds.

vi. The Engine Alternator sets transient response shall conform to IEEE requirements.

### b) Design Of Construction Requirements

i. Diesel generator sets shall be designed without harmful vibration stresses specially, during acceleration and deceleration.

ii. Harmful tensional vibration stresses shall not occur within the range 10% above to 10% below rated idle speed and from 15% above to 10% below rated synchronous speed.

iii. Moving parts shall be designed to withstand, without damage, 115% of the rated synchronous speed. However, the generator, exciter and flywheel shall be designed to withstand over sped of 25% without damage.

iv. DG Sets shall be able to withstand all stresses imposed during normal operation, testing and overload.

v. Equipment shall be designed and manufactured to withstand damage during transit, storage at site and after installation under the specified conditions.

vi. All dimensions shall be in mm. All nuts, studs and bolts shall be designed and fabricated to metric units.

vii. Nuts shall be hexagonal and bolt holes shall be spot faced for nuts.

viii. Materials shall be as per specifications and shall be new and first class in all respects.

ix. Castings and forgings shall conform to their respective material specifications and shall be free from flaws, machined true and a workman like manner.

x. Identical parts shall be interchangeable.

xi. The design shall provide for ease of access during inspection, maintenance, and repairs.

xii. Fuel oil and lube oil piping shall be located as far as possible away from engine exhaust lines. Pressurized lines shall be installed in such a way that damage to neighbouring equipment is prevented in the event of pipe break and pipe whip.

xiii. Materials for expansion bellows on exhaust and pressurized combustion air cooler and engine, silencer and exhaust pipe down streamside of silencer shall be of suitable grade stainless steel.

xiv. The coupling between engine and alternator may be rigid of flexible as required.

xv. Simplex filters with bypass filter for servicing shall be provided in lube oil circuits.

### c) Base

The DG units shall be mounted on a rigid fabricated steel sub – caste. Latitudinal beams shall be rigidly cross braced to avoid warping or bucking in transit or installation and the complete assembly shall be machined and drilled where necessary.

Anti-vibration mounding of an approved make shall be provided to absorb and damp out vibrations, which would otherwise be transmitted to the foundation and nearby structures.

**d) Tools**

A set general maintenance Basic tools shall be furnished for each DG set.

**e) PIPING (As Applicable)**

Piping for cooling water, oil etc, shall be designed fabricated and tested in accordance with IS / ISO pressure piping code.

All terminal connections and all pipe joints shall as far as possible be of welded constructions, screwed terminal connection shall be avoided.

Piping design and installation shall be suitable for periodic testing.

**f) Protection During Shipment**

Materials shall be handled and stored so that they are protected against corrosion, damage or ingress of foreign matter.

Flanges, openings, nozzles and terminals shall be thoroughly cleaned and adequately protected to prevent entry of extraneous material during transit and storage. Parts shall be suitably marked to facilitate matching during erection.

**g) Painting**

Machined and finished surfaces shall be protected against formation of trust and corrosion by application of a rust inhibitor.

All steel surfaces which are to be painted shall be thoroughly cleaned, degreased and given one shop coat of premier, prior to assembly.

All castings shall be sand blasted, degreased and cleaned before painting. Primary and final painting for work done at factory and site should be done by Concessionaire.

**h) Inspection**

The Concessionaire shall have rigid inspection procedure laid down to ensure quality of workmanship, compliance with material specifications and drawings, mechanical accuracy of components, identity and acceptability of all terminal, parts and equipment, both in his and his sub-Concessionaires works.

**6. Technical Requirements of The Diesel Engine and Auxiliary System**

***DIESEL ENGINE***

**a)** The diesel engine shall be four-stroke, single acting, mechanical injection type and shall furnished with at least the minimum equipment according to BS 5514 / ISO standard practices. The horsepower rating, required auxiliaries, guarantees of fuel consumption, parallel operation, governor characteristics and performance, torsional vibration and materials and workmanship shall be in accordance with BS 5514 / ISO standard practices.

**b)** The engine shall be equipped with a flywheel. The engine shall be provided with an exhaust gas turbo-charge with after – cooler and an integral air filter and silencer.

**c)** DESIGN AND CONSTRUCTION REQUIREMENTS OF DIESEL ENGINE

**i.BED PLATE**

Bedplates shall be of alloy cast iron or fabricated steel. In the case of steel bed plates, welding shall be done in a continuous process. The fabrication shall be stress relieved after welding.

**ii.CRANK CASE**

Crankcase shall be of alloy iron casting with integral transverse diaphragm or alternatively of fabricated steel construction provided with heavy steel inner side plates to form water compartments around the cylinders. Access to bearings, camshaft, governor drive and water jackets shall be provided in the webs, journals and bearings to carry lubricating oil under pressure to the main connecting rod bearings.

**iii. MAIN AND BIG END BEARINGS**

Main and big end bearings shall be detachable prefinished sheets with high-grade bearing materials and shall be easily fitted without scraping or hand fitting. The big end dimensions shall be such that the connecting rods can be withdrawn through the cylinder liners.

**iv.BALANCING GEAR**

Engine shall be inherently balanced. Where this is not possible, engine shall be fitted with a balancing system driven from the crankshaft.

**v.CONNECTING RODS**

Connecting rods shall be I beam sections of high grade drop forged steel and shall carry the big end bearings.

**vi.CONNECTING LINERS**

The cylinder liners shall be of the separately inserted ‘ Wet ‘ type cast in alloy iron and specially machined in their bores to give an oil retaining surface. They shall be flanged at their up ends and secured by the cylinder heads, with the lower ends located and sealed in the crank case by rings of synthetic materials resisting oil, water and heat.

**vii.PISTONS**

Piston shall be forged aluminum alloy or cast-iron alloy and machined on their outer surface to a system o graduated cold clearance to provide good heat transfer qualities and maximum bearings surfaces consistent with clearances. The pistons shall be fitted with compression rings and oil scraper rings of hardened cast iron alloy.

**viii.CYLINDER HEAD AND VALVE GEAR**

The valve operating gear assembly shall be oil lubricated and shall be oil totally enclosed in alloy iron castings bolted to the crank case with narrow joint washer interposed between the head and top of liner to provide a gas tight seal. Each cylinder head shall have inlet and exhaust valves of heat-resistant steel, which seat on wear – resistant inserts. Each cylinder head shall also be fitted with a fuel injector, combined pressure relief and compression release device, if required. the combustion chamber roof part walls and fuel injector sleeves shall e accessible for cleaning purpose. Each valve shall be loaded by concentric coil springs and shall operate in long detachable valve guides.

The valves shall be operated from the camshafts one for each bank of cylinders, by roller tipped cam followers. The valve gear mechanism shall be enclosed by light detachable covers.

**ix.CAMSHAFT**

The camshafts, one for each bank of cylinders, shall be build up in replaceable sections of heat-treated precision-machined steel with Chromium plating and jointed by muff-couplings, the outer diameters of each rotate in gun-metal. Bushes housed in the crank case casting. All cams shall have hardened profiles. Inlet and exhaust cams shall be in one piece and keyed to the soft. Fuel injection cams of the split removable type shall be down loaded in angler location.

**x.CAMSHAFT DRIVE**

The camshaft may be either chain or fear driven. Gears shall employ in the “hunting tooth” principle to ensure even wear. In the case of chain drives chain tensioning gear shall be located so that it is readily accessible.

**xi.FLY WHEEL**

The fly wheel shall be of mild steel statically balanced after machining and shall have graduated markings around its periphery to facilitate checking of valve and fuel pump timing. Flywheel shall have sufficient mass and inertia to meet specified limits of variation of generator eliminates torsional vibration within the operating speed limits of the governor and over speed trip, barring slots shall be provided around the flywheel rim of hand barring.

**xii.EXHAUST MANIFOLDS**

Exhaust manifolds may be single/double branch type insulated design utilizing Ni-resist Casting to guard against high temperature growth and cracking.

**xiii. FUEL OIL SYSTEMS**

Fuel oil will be stored outdoors in bulk oil storage tanks provided by the purchaser. The purchaser will provide pipe connections from the tank to the fuel-oil day tank.

The supplier shall provide a 990L day tank, fabricated out of sheet steel, for each DG sets. The day tank shall be situated outside a DG room on a suitable concrete Structure to be provided by the purchaser. The day tank shall be provided with necessary level controls to operate the alarm indications.

An engine driven pump shall be provided to deliver the fuel oil from the supply line through strainers containing closely oven filtering material to the injectors.

The supplier shall provide all necessary piping, fitting, supports, valves and accessories to complete the fuel oil system.

Each Day tank shall be provided with two [2] nos. level alarm switches for: -

High level (900 ltr ) / Low level corresponding to 30 mts fuel capacity of tank or 150 ltr.

Each tank shall be provided with a calibrated transparent tube for indicating the fuel level. Each tank shall be provided with a manhole, vent and drain nozzles, over flow pipe. Details of nozzles and also their orientation shall be furnished. All pipes shall be connected through flanged joints.

**xiv. FUEL OIL PIPING ROUTING**

Fuel oil piping routing inside the DG room shall be shown by the supplier. A single line diagram of the piping showing sizes of pipes, valves, etc., shall be furnished with the tender.

**xv. LUBRICATING OIL SYSTEM**

Automatic pressure lubrication shall be provided by a gear type pump at the free end of the engine and driven from the crankshaft. Pressure switches shall be provided to give alarm if the pressure falls below a set value and subsequently trip the unit when the minimum safe pressure limit is reached. A dipstick shall be provided for level measurement. All necessary accessories such as pressure gauges, temperature indicators, pressure relief valves, by pass valves, pressure switches for alarm and controls shall be provided by the supplier together with all interconnecting piping, fitting supports, valves etc.

**xvi. ENGINE STARTING SYSTEM**

Starting of the diesel engine shall be by electrical means. The diesel engine shall be provided with adequately rated battery of the lead acid type complete with all accessories, stand, interconnection etc.

**xvii. AIR INTAKE AND EXHAUST SYSTEM**

The supplier shall provide an air filter and residential type silencer with the turbo charger.

Air will be taken from the diesel room as started elsewhere in this tender.

The exhaust system shall consist of an exhaust gas driven turbo charger with lagged piping interconnecting cylinder head outlets with turbo charger inlets. Exhaust manifold shall be of fabricated steel and it shall be suitably lagged. Exhaust gas from turbo charger shall be led out through necessary pipes, adopters etc., to an exhaust gas silencer.

Expansion joints shall be provided to take care of thermal deformations. Pressure drop in the exhausts piping including silencer, bends, expansion joints etc., shall be compatible with exhaust gas leaving the engine. The exhaust piping shall be duty throughout the length from the engine outlet up to the outlet point inside the room with high temperature resistant thermal wool, with chicken mesh and on top lagged with aluminium sheet wrapping. Bending radius of bends shall be not less than 3 internal diameters of chosen piping. A drain plug shall be fitted at the lowest point for condensate extraction. Exhaust pipe shall be raised above the highest point of the building and shall meet the regulations of pollution control board. Suitable supports shall be provided for proper installation of exhaust pipe.

The silencer shall be mounted so that its weight is not supported by the engine. Exhaust pipe size shall be sufficient to ensure that the exhaust back pressure does not exceed the maximum limitations specified by the engine / generator set manufacturer. Piping size shall not be less than 10” dia with B Class MS pipes duly supported.

The muffler and all indoor exhaust piping shall include lagging to maintain a surface temperature not exceeding 65 Deg; C. The insulation shall be installed so that it does not interfere with the functioning of the flexible exhaust fitting.

Engineering data sheets detailing silencer attenuation, construction materials and all relevant physical dimensions in detail shall be provided. Data shall include bends, necessary adapters, tail pipe, brackets, supports, joints, bolts, diameter of exhausting piping, size of thimbles for penetrating walls, type of insulation for silencer, etc.

Exhaust system shall consist of the following:

- Exhaust pipe & Bends: Class ‘B’ M S pipe,
- Special exhaust silencer insertion loss value 25 dB (A),
- Freestanding chimney as per the specifications.

**d)** GOVERNING SYSTEM

The digital governing system shall conform to accuracy class A1 as per BS 5514: Part 4. In addition, when a 93KW motor for 2000KVA having a starting current of 3 Full load current (FLC) is started, the frequency dip and recovery time shall not be more than 5% and 3 Secs respectively.

Governor shall have the following features.

i. It shall be capable of operating both as an 'isochronous' or a 'speed droop' governor. The speed parallel operation shall be adjustable from 0-5% of the engine.

ii. The governor system shall be provided with electronic devices, which would sense change in generator kW load and initiate corresponding change in governor setting prior to a signal being received from normal speed governing.

iii. Governor shall be suitable for operation without external source of power supply.

iv. A KW load sensing facility shall be available in the engine governor / controller. A over speed trip shall be provided to automatically shut off fuel in case the set reaches 110% rated speed.

v. An engine mounted emergency stop push button shall be provided.

vi. REQUIREMENT OF SPEED GOVERNOR

Speed governor shall have steady state transient response and recovery times fully conforming to class A1 governors as per BS 5514 part-IV.

vii. MOTORS FOR AUXILIARY SYSTEMS

Motors if any for the auxiliary systems shall be suitable for 3 Phase, 415 +/- 10%, 50Hz +/-3% AC supply. Motors shall comply with the requirements of BS 4999 and BS 5000 for power station auxiliary duty. Degree of protection of motors shall conform to IP 55.

**e)** REQUIREMENTS OF GENERATOR AND EXCITATION SYSTEM

**i. SCOPE**

This specification generally describes the generators and associated equipment, excitation system and voltage regulator.

**ii. STANDARDS APPLICABLE**

The Equipment and accessories covered by this specification shall be designed, Manufactured and tested incompliance with the following latest relevant standards in order that specific aspects under working conditions are taken care of:

The

| | |
|---|---|
| 1. a. IEC Publication No.34-1 | : Recommendations for rotating electrical machines. |
| b. IEC Publication No.34-1A | : Supplement to publication No.34-1 |
| British Standard 4999 | : Specification and general requirements for rotating electrical machinery. |
| Indian Standard 4722:1968 | : Rotating electrical machinery |
| IEEE: 115 | : Test Procedure for synchronous machines. |
| IS 4691 / 1968 | : Degrees of protection. |

equipment and accessories for which Indian standards are not available shall be designed, manufactured and tested in accordance with the latest standards published by other recognized national standards institution.

The equipment shall also conform to the latest Indian Electricity Rules as regards safety, earthing and other essential provisions specified there in for installation and operation of electrical plants.

**iii. GENERATOR SPECIFICATIONS**

The alternator shall be continuously rated, three phase. Three wire, rotating field, self-excited, brush-less type alternating current machine, direct coupled to the diesel engine prime mover. The whole unit shall be designed and constructed to operate as one unit. Mechanical degree of protection of alternator shall conform to IP-22.

The diesel engine and alternator shall be mounted on a common steel base frame for grouting into or floating on a concrete foundation for fitting to embedded steel channels. Coupling shall be provided with coupling guards.

The deviation factor of the open circuit line-to-line terminal voltage of the alternator shall not exceed 0.1.

Alternator shall be capable of withstanding, without damage a 30 second three phase short circuit at its terminals when operating at rated KVA and power factor at 5% over voltage, with fixed excitation.

Alternator shall be capable of carrying a one-minute overload of 50% of normal rated current with the field set for normal rated load excitation.

Alternator shall be designed to be capable of operating in parallel with other DG sets of similar rating and / or grid.

Alternator winding shall be insulated with class F insulation. The machine shall be naturally ventilated. 3 wire type embedded temperature detectors for winding and bearing shall be provided.

Alternator shall have amply dimensioned terminal boxes for easy termination of aluminium power cables to terminate leads from space heaters; windings and bearing temperature detectors; to accommodate protection CTs.

Terminal box shall be suitable for cable entry from top bottom or sides.

**iv.GENERATOR REACTANCE:**

Sub-transient reactance shall be low to maintain fault contribution from the generation within permissible limits. The transient reactance should be as low as possible consistent with the need to limit voltage drop on sudden application of load.

**f) Generator Construction**

**i.** GENERAL

All parts of the generator and accessories shall be capable of withstanding electrical, mechanical, thermal and other stresses experienced in operation and during short consistent with the need to limit voltage drop on sudden application of load.

Spacer blocks and wedges used in the construction of stator windings shall be made of non-shrinkable material. Binding of coils shall be non-continuous, preferable using glass cord or equivalent. Generator stator and field windings shall be insulated with class F insulation. Core plate insulation shall also be class F. All armature winding connections shall be brazed strand to strand to provide maximum margin against local overheating.

**ii.**BEARING INSULATION

Insulation shall be provided to break the paths of stray current at two places in series with provision made for determining the insulation resistance each insulation piece. The insulation under the bearing pads shall be made of non-hygroscopic material.

**iii.STATOR** FRAME

Stator frame shall be of one-piece construction, fabricated from heavy steel pipe and designed for minimum noise and vibration.

All stationary parts of the generator shall be designed to avoid resonance at 50Hz, 100Hz and 200Hz.

Generator shall be designed with B3 construction i.e., with two end shields and foot mounted.

**iv.ROTOR**

Rotor shall be properly balanced at rated speed, critical speeds over speeds.

**v.VENTILATION**

Generator shall be air cooled with shaft mounted fan.

Shaft mounted fans shall be provided to effect air circulation through the ventilation system.

**vi.CONNECTION**

The 3 phase windings of the generator shall be arranged for star connection and shall be suitable for operation with

the neutral grounded.

**vii.**STATOR **TERMINALS** AND TERMINAL ARRANGEMENT

The two terminals of each phase winding shall be brought out of the generator frame at approved locations. Terminal markings shall be in accordance with BS 622. The direction of rotation shall be marked on the suit purchaser's cables/ bus ducts and enclosed to safeguard against short-circuits by rodents etc., Suitable cable glands or cable sealing boxes as specified shall be provided on the enclosure to facilitate entry of the cables.

**viii.TERMINALS**

The lines and neutral ends of each phase winding of the generator shall be brought out two separate terminal boxes. The line end terminal box shall be phase segregated for HV machines and phase insulated for LV machines. Terminals boxes shall have facilities for mounting CTs specification on 6 suitable located terminals.

Cables sizes shall be as indicated in the Generator Data Sheet enclosed, if applicable.

Fault withstand capability of the terminal box shall be 21 KA for 1 Sec.

**ix.CURRENT TRANSFORMERS**

Current transformers, two per phase shall be provided at the neutral end of the generator with rating as in Generator Data Sheet for over current, differential and restricted earth fault protection.

Offer for current transformers shall be accompanied by Ratio and phase angle errors and complete error for protection class CTs

Magnetization characteristics extending at least up to 150% of the excitation current at knee point voltage for both class PS and protection CTs.

Current transformers shall have terminal blocks with facility for short circuiting grounding the secondary.

**x.TEMPERATURE DETECTORS**

A minimum of two platinum resistance type temperature detectors shall be provided per phase of the generator, between the coils of the stator windings and two on bearings. The resistance value of the RTDs shall be 100 ohms at 0 deg C. The supplier may provide additional RTDs for measuring temperatures at specific points in the machine. In addition to RTD, supplier may provide additional monitoring equipment if required to monitor equipment condition.

Temperature detectors of resistance type shall be provided, in accordance with America Standard SpecificationC.50-1. One RTD shall be embedded in each bearing.

The detectors shall be installed at locations where the highest temperatures may be expected. The leads of the temperature detectors shall be brought in a neat and adequate manner to an easily accessible terminal box on the generator frame. The minimum size of the leads shall be 1.5 Sq.mm. The leads shall be protected against stray electrical fields mechanical damage.

The temperature detectors with their leads shall be accurately calibrated. Test reports giving results of the calibrations shall be submitted for purchaser's scrutiny.

A drawing indicating locations of the detectors shall be furnished.

**xi.SPACE HEATERS**

Space heaters of adequate capacity rated for 240V, 50Hz single phase service shall be provided for the generator, exciter, and associated cubicles to maintain inside temperature sufficiently above outside ambient so that condensation o atmospheric moisture is prevented when the equipment is not in service.

The heaters shall be mounted in an accessible location. In the case of the machines, they shall be located in the lower part. Terminals of the space heaters shall be brought out to a separate terminals box.

KW rating of the space heater shall be indicated.

**g) EXCITATION SYSTEM**

**i.BRUSH LESS EXCITATION SYSTEM**

a. The brush less excitation system shall have the following provisions: -

b. A revolving armature AC exciter directly coupled to the generator rotor at the outboard end shall be provided. The output of the AC exciter shall be rectified by the rotating diodes connected as a 3-phase bridge.

c. The rotating rectifier components shall be contained against centrifugal forces by adequately designed retaining ring. The rectifier design shall be based on one high power diode and fuse per parallel path. Suitably rated heat sinks which will also act as a fan shall be provided for each diode.

d. DC outgoing poles shall preferably be segregated by locating Rectifier Bridge on either side of the shaft. Each arm of the bridge shall be made of more than one high power diode arm arrangement in a suitable configuration to ensure that the cells withstand all fault conditions to which they may be subjected.

e. The total number of diode arms shall be such that failure of up to 25% diode arms will not cause restrictions on the unit operation at its rated condition, including field forcing. Suitably rated varistors etc.., shall be provided to give a path for the reverse polarity induced currents resulting from the generator pull-out, power swing and any other abnormal conditions. Diodes and associated protective devices shall be mounted radially. It shall be ensured that the rectifying junctions are held in compression under speed.

f. Excitation system shall have thermal capability equal to or better than the field of requirement of the generator, when operating at rated KVA and at any voltage between 5% below and 5% above rated voltage.

g. Exciter rated voltage shall be at least 110% of the rated machine excited voltage. Exciter ceiling voltage shall not be less than 130% of the exciter rated voltage.

h. Insulation of exciter shall be class F.

**ii.**VOLTAGE REGULATOR

a. The voltage regulator shall be automatic, high speed, non- band type with provision for current compounding. The voltage regulating system shall be suitable for automatic control of voltage.

b. Steady state accuracy of the voltage regulator from non-load to rated load shall be within +/-2.5% of rated generator voltage of any one phase at any p.f between 1.0 and 0.8 lagging from cold to hot variations.

c. The voltage regulator shall be capable of supplying excitation current in the event of a 3-phase short circuit at the generator terminals to facilitate operation of the protective devices and under all conditions of loading specified.

d. Alternator shall have a reliable 3 phase voltage sensing compound excitation system having:

e. Capability to build-up the voltage from residual magnetism.

f. Protection against low-speed operation.

g. Voltage / hertz responsive feature.

h. Provision to manually adjust the alternator voltage within +/- 5%

**iii.**GROUNDING

A non-corrodible metal pad shall be welded or brazed at two different locations on the frame and shall have a threaded hold at the center for connecting the cable lugs by means of hexagonal head bolts and spring washers.

Two independent grounding points shall be provided on opposite sides near the bottom.

Grounding points shall be suitable for the following grounding strip.

- Machine : 50 X 6mm Cu. Flat
- Power Panels : 25 X 6mm Cu. Flat
- Control Panels : 25 X 3mm Cu. Flat

**h) Performance Requirement of the Diesel Generator Units**

**i.**The DG sets and the associated auxiliary system shall be designed to provide a standby source of power of a high reliability.

**ii.**The DG set shall be capable of starting from cold condition and reaching synchronous speed and ready to take load in a period of ten (10) seconds from the initiation of start impulses without suffering undue stress, wear and tear. The DG sets shall be capable of accepting the maximum rated load of the generator within a period of thirty (30) seconds from the initiation of start impulse.

**iii.**The DG sets shall be capable of operating at rated load on the generator

- in isolation

- in parallel with similar DG sets.

**iv.** Diesel generator shall be capable of delivering continuously at the terminals of the alternator 1600 kW Prime duty for 2000 KVA sets at 0.8 P.F at 11KV when the ambient surrounding the alternator is between -15 deg c to 30 deg C, intake air for combustion 30 deg C.

**v.** The DG sets shall be capable of peak-output of 10% in excess of the rated output for a period of one (1) hour in every 12 hours of continuous running at rated load, without exceeding permissible temperature limits and with a faintly visible exhaust.

**vi.** The DG sets shall be capable of meeting the specified performance when using commercially available HSD oil to as per IS: 1460-1974.

**vii.** The DG sets shall be capable of starting on their own when external power supply is not available

**viii.** Diesel generator shall maintain output accuracy of +/-1% of voltage and +/- 0.25% of frequency at the terminals of the alternator under steady state condition.

**ix.** During recovery from transients caused by step load increase or resulting from the disconnection of the largest single load the speed of the D.G.set shall not exceed 115% of the nominal. Further, the transient following the complete loss of load shall not cause the speed of the unit to attain the over speed set point.

**x.** The sub transient and transient reactance of the generator shall be chosen to meet the above requirements.

**xi.** The voltage and frequency of the generator shall be adjustable between + / - 5% and + / - 2.5% of the nominal values respectively from local D.G. control panel and remote-control panel.

**i) Items of Guaranteed Performance**

**i.** Following items of performance shall be guaranteed by the supplier in respect of the DG sets and auxiliaries, when operating under specified site conditions.

**ii.** Net electrical power output at specified power factor and terminal voltage under specified conditions considering de-rating factors as given in ISO standards.

- Fuel oil consumption at full load.
- Lubricating oil consumption at full load.
- Jacket water temperature to and from engine. (As applicable)
- Lubricating oil temperature to and from engine.
- 10% overload for one hour in every 12 hours of continuous running at rated load.
- Generator efficiency at ½, ¾ and full load at specified power factor and terminal voltage.
- Governor response and over speed capability.
- Voltage regulator response.
- Concessionaire shall indicate the tolerance applicable to each of the guaranteed parameters above and the reference standard.

**j) DIESEL ENGINE DRIVEN GENERATOR**

The engine/generator sets shall meet the following parameters:

- A governed speed of 1500 rpm.
- Rated 0.8-power factor for prime operation.
- To operate at 11000 Volts, 3 phase, 3 wires, 50 Hz at 5000 meters elevation above sea level.
- Temperature range of 15 Deg; C to 35 Deg C.
- Equip generator with a liquid cooled diesel engine.
- Engine-mounted radiator
- Alternators shall be of reputed make, salient pole, brush less, synchronous, revolving field, air-cooled and drip-proof and OPEN DELTA connected with a separately excited system using a permanent magnet generator.

- The alternators shall be capable of withstanding, without adverse effects. Over-speeds of 25 percent above the governed speed for the duration of one minute.
- Generators shall have the capability to provide minimum of 300 percent of rated three-phase current for 10 seconds.
- Engine mounted fuel filter.
- Phase segregated terminal box shall be provided which shall be suitable for terminating 11KV 3C Ar Al. XLPE, earthed type cable. The neutral terminal shall be brought out in a separate terminal box on the opposite end.
- THD at no load shall be < 3%
- 3 Nos. single phase 11 kV / 110 V /√3 PTS shall be supplied for AVR sensing.
- Exhaust System – Exhaust system shall be connected to a freestanding chimney. The chimney shall be suitable for connecting all Generators.

**k) Requirements of 2000 KVA, 11 KV D.G. Set.**

**i.**DIESEL ENGINE:

Diesel Engine, Radiator Cooled, Turbo charged, with After Cooler, suitable for Generating Set applications, developing 2319 BHP for 2000 KVA DG SET @1500 RPM under NTP conditions of BS:5514, with an overload capacity of 10% for one hour, in any 12 continuous hours operation. The Engine is equipped with the following standard accessories as per the specification given in this Tender.

**ii.**COOLING SYSTEM

Consists of Radiator with Fan, Engine Mounted Water Pump, Thermostat, Corrosion Inhibitor Coolant and Self Control piping.

**iii.**FUEL SYSTEM

Consists of PT fuel pump, Injectors, Fuel Filters and Self-Contained piping.

**iv.**LUBRICATING SYSTEM

Consists of Oil Pump, Strainer Lube Oil Cooler, Oil Filter, Bypass Filter and Self-Contained piping.

**v.**AIR INTAKE SYSTEM

Consists of Dry Type Filter, Air Cleaner Manifold with necessary connections and turbocharger with after cooler

**vi.**EXHAUST SYSTEM

Consists of Exhaust Manifold, Flexible and Residential Silencer.

**vii.**GOVERNING SYSTEM

Digital Governor Controller.

**viii.**STARTING SYSTEM

24V D.C. Starter Motor, Battery Charging Alternator with in-built regulator.

**ix.**DG CONTROLLER PANEL (Near the DG set) Consists of the following parameters with Digital indication.

a. Water Temperature.

b. Lube Oil Pressure.

c. Engine RPM.

o Running Hours.

o Fault code display

o Emergency push button

o Auto – Manual selector

Other feather touch switches:

**x.**In the Relay metering Panel

a. Battery Voltage.

b. Voltage between phases

c. Current in each phase

d. Power Factor

e. KWhr

f. Battery charger failure.

**xi.** Trip Indication LED Red Display for

a. High Water Temperature.

b. Engine Over Speed.

c. Low Lube oil pressure.

d. Low Coolant Water Level.

e. Battery charger failure.

f. Sensor Fault.

**xii.** Accessories

a. Flywheel Housing.

b. Flexible Coupling.

c. Coupling guard.

**xiii.** ALTERNATOR

Standard design Alternator rated at 1600 KW for 2000 KVA DG SET at 0.8 PF, 11 KV, 3Phase, 3 wires, 1500 RPM, 50 Hz. Brush less design in screen protected, drip proof, IP :22 enclosure with WTD & BTDs, Space Heater Insulation Class "F" Band of Voltage Regulation +/- 2.5% of rated voltage from no load to full load. The Alternator generally conforms to BS: 2613/5000.

**xiv.** BASE FRAME

Sturdy, Fabricated, Welded construction, Channel Iron Base Frame for mounting the above Diesel Engine and Alternator.

**xv.** FUEL TANK

990 Liters capacity Fuel Tank for ONE each DF with supporting stands complete with level indicator, fuel inlet and outlet, air vent, drain plug, inlet arrangement for direct filling and set of 5 ft. long fuel hoses.

**xvi.** BATTERIES:

Set of 4-Nos. 12 Volts, 27 Plates, Dry Uncharged Batteries.

**xvii.** ANTI VIBRATION MOUNTS:

Set of Anti Vibration Mounting Pads.

| **GENERATOR DATA SHEET** | |
|---|---|
| Rated frequency | :50 Hz |
| Number of phases | :3 |
| Winding Connections | : Wye |

| **GENERATOR DATA SHEET** | |
|---|---|
| Generator continuous outputs rating | :1600 KW (2000 KVA) |
| Rated Voltage of Generator | :11000V |
| Power factor | :0.8 lag |
| Over load capacity for one (1) h in every 12 h of continuous running at rated load | :10% |
| Type of insulation<br>a. Armature winding<br>b. Field winding<br>Connections<br>Core Insulation | <br>: Suitable for 11000V<br>: Suitable for 11000V<br>: Suitable for 11000V<br>: Suitable for 11000V |
| Temperature rise at max. Continuous Rating over 40 deg C<br>a. Armature winding (by resistance)<br>b. Field winding (by resistance)<br>c. Core and mechanical parts in contact with adjacent insulation (by thermometer) | Temperature rises as per standards<br>: 100 Deg C<br>: 100 Deg C<br>: 80 Deg C |
| Type of enclosure | Screen protected drip-proof IP22 |
| Permissible voltage variation of voltage for satisfactory operation at rated KVA, rated Speed and rated power factor | +/-1.5% |
| Excitation system | Brush less type rotating armature, stationary. |
| Voltage regulator<br>a. Voltage setting range of the regulator voltage.<br>b. Steady state accuracy of voltage<br>c. Quadrature droop circuit provided limit the reactive KVA | <br>+ / - 5% of rated<br>Less than + /- 0.5 of regulator from no-load to rated generator voltage full load<br>: Yes |

| **GENERATOR DATA SHEET** | |
|---|---|
| Maximum period to recover the Generator voltage to the set value for a step application or rejection of rated power factor. | : 0.5 sec |

## l) TECHNICAL SPECIFICATION FOR NEUTRAL ISOLATOR WITH NEUTRAL GROUNDING RESISTOR PANEL

i.SCOPE

This specification generally describes the neutral isolator and neutral grounding resistor panel and associated accessories.

ii.STANDARDS APPLICABLE

The Equipment and accessories covered by this specification shall be designed, Manufactured and tested incompliance with the following latest relevant standards in order that specific aspects under working conditions are taken care of:

IEEE-32 for Resistance rating & temp is concerned IS-2147 for the type of enclosure.

iii.GENERAL CONSTRUCTION

a. Free standing, Floor mounting, Indoor type, Panel fabricated out of CRCA sheet of 2mm thick with suitable reinforcements and with louvered sheets provided on outside and covered with fine mesh to make the unit vermin proof.

b. 11 kV, 100A, vacuum contactors shall be used for the D.G. Set Neutral Isolation. The Neutral Grounding resistors shall be provided in the neutral earthing conductor to limit the fault current to 100A in the event of a line to ground fault.

c. The resistance shall be of Punched stainless steel material and rated 100A for 10 sec with resistor value of 63.5 ohms.

d. The top of the resistor portion will have a perforated sheet of 2.1mm hole to let out the heat dissipated by the NGR during fault conditions.

e. The paint finish shall be of Siemens gray as per shade RAL – 7032 both inside and outside.

f. Foundation holes will be provided in the bottom channel base of the unit for grouting the panel to foundation. The cable entry can be either from Top of Bottom through undrilled removable type Gland plates.

iv.RESISTOR BANK CONSTRUCTION

The grids will be of punched out of SS steel grade ASTM-A240-304. Grids thus will made will be assembled on to a threaded MS rods having interleaving porcelain separators as inter grid insulation. The Inter grid connection is by SS hardware. The resistance will be assembled in the form of banks and the number of banks will be stacked one above the other in the Resistance compartment.

v.REQUIREMENTS OF NGR PANEL

The panel shall comprise the following components.

a. 1 No. 11KV, SP, 400A Vacuum contactor rated suitably with aux. contacts.

b. 1 No. 11KV Epoxy Cast Resin CT, Ratio 50 / 5, 5P10, 15VA for E/F Relay.

c. 3 Nos. 11KV Epoxy Cast Resin CT, Ratio 150 / 5A, 15VA, PS class for Differential Protection.

d. 1 Set of reputed make panel Lamp, Panel Heater, and Control Fuses.

e. 1 Set of 100A Rated Aluminium Busbar.

f. Sets of Punched SS Grid Resistor unit of rating 100A, 63.5 ohms, 10 Secs with a Max.Temp.rise of 375deg C.

g. Sets of Green & Red Indicating Lights for Isolator ON / OFF.

h. Sets of CT & Control Terminals.

By using a combination of isolating devices as per the Single Line Diagram enclosed, flexibility of running the Generators in Solo & Parallel modes are possible. The remote switching of the Isolating devices may be done by using either a PLC or Contactor Logic and the scope of the same is to be included in the offer.

vi.GUARANTEED TECHNICAL PARTICULARS

(Of the Grid Offered – Punched SS)

| | |
|---|---|
| Type of Grid | : Punched SS. ASTM-A240-304 |
| Ohmic Value | : 63.5 ohms |
| Tolerance on cold ohms | : + or –7.5% |
| Duty Rating | :10 Secs |
| Rated voltage | :11 KV |
| Rated Current | : 100 Amps |
| Type of Cooling | : Natural Air |
| Type of enclosure | : IP-42 (Panel) |
| Installation | : Indoor |
| Interconnection | : 25 X 6 mm Copper Flat |
| Max.Temp.rise: | |
| Resistor | : 375 deg C as per IEEE-32 |
| Enclosure | : 55 deg C as per IEEE-32 |
| Type of protection for | : Resistor portion |

vii.TESTING

The following tests shall be conducted at your works on each of the equipment and in house test certificates shall be given in duplicate for reference & records.

a. Cold Ohmic value test at room temperature (within + or – 7.5% tolerance)

b. Megger test between grids & ground by 2500V meggar.

c. High Voltage withstand test of 2.5KV for 1 minute for LT circuit.

d. High Voltage withstand test of 28KV for 1 minute for HT circuit.

**m) DG POWER SYNCHRONISATION SYSTEM**

i.Functional Requirement

a. DG Monitoring and Controls including Synchronization, Load sharing between the DGs.

b. Communication with the DG Electronic Governors on hard wired interface.

c. Power monitoring and Breaker status monitoring at the main incomers of the DGs

d. Accurate Power monitoring at the various down side feeder points like AC Loads, Lighting loads, Water Treatment Plant etc., This should also enable Tariff Calculation Development wise / area wise.

e. Control and individual breakers up to the block loads to enable load shedding. The load shedding scheme should be in the order of priority / criticality.

f. Integration with SCADA System to enable effective ventilation system control and load shedding.

ii. SYSTEM DESCRIPTION

a. The system shall be equipped with load demand monitoring and control to automatically program the generator sets to start, parallel and share system loads, which includes the control of all outgoing changeovers. This shall include: Power monitoring of all Generators and transformer.

b. Auto Load sharing between the generators.

c. The switchgear load sensing circuits shall monitor station load demand and determine how many generator units are to run, when they are to be started, stopped, and at what levels of loads. The system load circuits shall be kilowatt sensing from the switchgear bus and completely adjustable.

d. Adjustable time delays shall be incorporated in the pickup and drop-off load sensing circuits to avoid unnecessary starting and stopping on load surges. Load sensing circuits shall be automatically passed to the next sequenced generator unit, if any safety shutdowns occur.

e. The system shall include automatic and manual, control to fully utilize the available power.

f. At no time shall the generators be paralleled with the utility.

iii. PROGRAMMABLE LOGIC CONTROLLERS (PLC)

All required logic shall be derived using a PLC. It shall have facility for monitoring the status of the generator parameters and breakers, generating alarms, controlling the breakers and for monitoring the power at every breaker. The output relay contacts shall have adequate making and breaking capacity. All necessary transducers for inputting the data to the PLC shall be in the supplier's scope.

iv. SYNCHRONIZATION

The PCC (Power command controller) or Generator Synchronizing Module (GSM) takes Current Transformer (CT) and Potential Transformer (PT) inputs from the synchronizing bus and PT inputs from the reference bus and shall perform the following functions:

a. Synchronization.

b. Load sharing (Active & Reactive).

c. Anti motoring.

d. Power monitoring.

This feature shall facilitate the automatic synchronization of generators onto a reference bus. The PCC / GSM shall compare the synchronizing and reference bus parameters continuously. When the synchronization conditions are met, the PCC / GSM shall issue a "close breaker command" to close the breaker.

When the system reaches the required limits the PCC / GSM shall give a command to the PLC or directly to close the breaker, in turn synchronizing the Generator with the other generator sets.

v. LOAD SHARING

Apart from auto synchronization, the PCC / GSM shall have a built-in load sharing feature. Active load sharing shall be achieved by adjusting the engine speed via the governor, whereas Reactive load sharing shall be achieved by varying the AVR. These commands shall be generated by the PLC / PCC and the outputs given shall be potential free contacts.

vi. POWER MONITORING

In addition to the synchronization function, the PCC / GSM shall provide extensive array of monitoring information for systems wired in Wye Delta or open delta. The PCC / GSM shall monitor different electrical parameters of the synchronizing bus and parameters of the Reference bus.

vii. COMMUNICATION WITH GOVERNOR

The interface with the generator governors shall be of a format suitable for effective communication with the electronic governor fitted to the generators.

The interface shall be able to:

(a) Effectively raise and lower the speed of the engine.

(b) Provide all the engine related data including diagnostics and Alarm information from the engine.

**n) TECHNICAL SPECIFICATION FOR RELAY, MONITORING AND ANNUNCIATION PANEL.**

i.SCOPE

This section describes the requirement of control, instrumentation and protection for the diesel generator sets.

ii.CODES AND STANDARDS

The design, manufacturing and performance of equipment shall comply with all currently applicable standards, regulations and safety codes in the locality where the equipment will be installed. Nothing in this specification shall be construed to relieve the vendor of his responsibility.

Unless otherwise specified, equipment shall conform to the latest applicable Indian or IEC Standards. The Indian Standards is IS : 8623.

iii.CONTROL AND ACCESSORY EQUIPMENT

110V DC will be provided by the purchaser. If voltage other than 110V DC is required by the supplier, necessary arrangement shall be made by the supplier, necessary arrangement shall be made by the supplier, within the cubicle, to obtain the necessary voltage/s by providing transformers, inverter / Converter etc.

Control supply shall be controlled within the cabinet by adequately rated heavy duty, load break isolator / switch, HRC fuses, MCB etc., as the case may be.

iv.AUXILIARY CONTACTOR FOR BATTERY CHARGER.

A suitable auxiliary Concessionaire shall be provided for connection the battery charger to the main supply. A contactor shall be provided with an isolating switch and shall be so arranged as to disconnect the battery charger during engine starting.

v.FUSES

All fuses shall be of HRC cartridge conforming to IS : 2208 mounted on plug in type fuse bases having a prospective current rating of not less than 80 kA. Fuses shall be provided with visible operation indictors to show that they have operated. All accessible live connections shall be adequately shrouded, and it shall be possible to change fuses with the circuit live, without danger of contact with live metal. Insulated fuse pulling handle shall be supplied with each control cabinet.

vi.INSTRUMENTAL TRANSFORMERS

Current and Voltage transformers shall conform to the requirements o IS : 2705 and IS : 3156 respectively. Unless otherwise specified it shall be the responsibility of the vendor to ensure that the class and VA burdens of instrument transformers provided are adequate for the meters and relays connected to them. Facilities shall be provided to short circuit and ground the CT secondary in the CT secondary leads to carry out current and ground the CT secondary in the CT secondary leads to carryout current and phase angle measurements with CTs in service. Voltage transformers shall be provided with suitably rated primary and secondary fuses.

vii.CONTROL TRANSFORMERS

All AC control equipments shall be suitable for operation on 1 phase, 110V, 50Hz system. Suitable rated 415 / 110V control transformers as required shall be supplied as an integral part of the control cabinet. Each control transformer shall be complete with isolation facilities, primary and secondary HRC fuses. One end/ center point of the control transformer secondary shall be earthed.

viii.INDICATING INSTRUMENTS & METERS

Electrical indicating instruments shall be of moving iron type having 144mm square, 90 deg scale. These shall be mounted flush on the panel with only the flanges projecting. Dials shall be while with black numbers and lettering. Parallox free dial shall be provided. Ammeters measuring upto 10A shall be directly connected, while those measuring above 10A shall be connected through CTs. Voltmeters shall be connected through suitable selector switches and protected by the indicating instruments and meters shall be 1.0

ix.RELAYS & TIMERS

All protective relays shall be of rectangular in shape, suitable for flush mounting with only the dust tight covers projecting beyond the cabinet door. Relays shall be equipped with external reset, positive action operation indicator visible from the front. Voltage relays shall have sufficient capacity for continuous energisation, using external resistors, if necessary.

Unless otherwise specified, auxiliary relays can be of fixed type mounted inside the cabinet but shall be provided with individual dust-tight covers. Auxiliary relays shall be rated to operate satisfactorily between 70% and 100% of rated voltage.

Number of relays and timers shall be as pr requirement. The relay / timer coil voltage shall be 110V DC. There shall be adequate spare contacts which shall be exclusive for the use of purchaser. All contacts on relays / timers shall be wired up to terminal blocks.

x. CONTROLS & SELECTOR SWITCHES

Control and instrument switches shall be of totally type having enclosed contacts which are accessible by removing the cover and shall be provided with properly designated escutcheon plates. Clearly marked to sloe the operating positions. Control switches shall have momentary contacts, spring return to center, with pistol- grip handle. Instruments and selector switch shall have stay-put contacts. The number of contacts and their operation in each switch shall be as per the requirements of the connected circuit.

xi. PUSH BUTTONS

All push buttons shall be to push-to actuate type having 2 NO and 2 NC self reset contacts, they shall be provided with integral escutcheon plates, engraved with their functions.

xii. INDICATING LAMPS

Indicating lamps shall be of the filament LED type having double contact bayonet caps and low watt consumption. Lamps shall be provided with series resistors.

xiii. SPACE HEATER

Strip type space heaters of adequate capacity shall be provided inside each cabinet to prevent condensation of moisture. Space heaters shall be rated for 1 ph, 240V, 50Hz supply. Heaters shall be complete with ON-OFF switches, HRC fuses in phase, link on neutral and a thermostat to control switching of the heater. Power supply shall be provided from purchaser's panel.

xiv. INTERIOR LIGHTING AND RECEPTACLES

Control cabinet shall be provided with a 1 ph, 240V, 50 Hz lighting fixture for interior illumination controlled by an ON-Off switch. In addition to the above, a 1 ph, 240V, 50Hz, 3pin receptacle shall be provided.

xv. ALARM AND SUPERVISION SYSTEM

The alarm and supervision system shall have:

a. A push button for clearing the audible alarm (visual annunciation will persist)

b. A push button for clearing the visual annunciation after the fault has been cleared.

c. A push button for testing the illuminated transparencies.

d. All alarm devices shall be suitable for operation on 110V DC.

xvi. PANEL INTERNAL WIRING

a. Control panel shall be supplied completely wired, ready for purchaser's external connections at the terminal's blocks. All wiring and cables shall be carried out with PVC insulated, stranded copper conductor wire / cables. Power circuits shall be wired with stranded copper conductors of adequately sized to suit the rated current. The minimum size shall be 4sqmm control, alarm indication circuits shall be wired with stranded copper conductors of size not less than 1,5 Sq. mm CT circuits shall be wired with stranded copper conductor size not smaller than circuits shall be wired stranded copper conductor size not smaller than 2.5 Sq. mm

b. Power and control wiring shall be separately run and neatly bunched.

c. Wiring affected by stray electromagnetic fields shall e suitably shielded or run as twisted pairs where applicable.

d. Wiring for control switches, lamps, meters etc., mounted on doors shall be bunched together and supported in a loop in order to prevent any excess strain being applied to the wiring when the door is opened.

e. All covers both internal and external, which are removable to allow access to compartments shall be inscribed 'Danger'.

f. Engraved core identification ferrules, marked to correspond with the wiring diagram shall be fitted at both ends shall not fall off when wire is removed. Spare auxiliary contacts of all relays, contacts etc., shall be wired to terminals blocks.

g. All wiring shall be terminated on terminal blocks using solder less crimping type tinned copper lugs. Insulating sleeves shall be provided at all the wire terminations. All wiring shall be nearly bunched and cleared within the cabinet. Wiring troughs shall be provided for vertical panel wiring and for interconnecting wiring between front and fear and rear section of the cabinet.

h. One piece moulded, 650 V grade terminal blocks complete with insulated barriers, terminals studs, washers nuts and lock nuts and identification strips shall be used. Terminals for power connections shall be adequately rated for the circuit current and the rated for other terminal blocks for control etc., shall not be less than 15A. At least 20% spare terminals shall be provided. Terminal blocks for control, indicating etc., shall be suitable for connecting two conductors of purchaser's cables of following sizes: -

| | | |
|---|---|---|
| 1. | Potential and control circuit | Two of 2.5 Sq mm stranded Copper conductor. |
| 2. | CT Circuits | Two of 4 Sq mm or four of Sq mm stranded copper, conductors. |

Terminal blocks shall be numbered for identification and grouped according to function. Terminal blocks for CT secondary loads shall be provided with short circuiting and earthing facilities. There shall e minimum clearances of 250mm between the first row of terminal blocks and the associated gland plate. Also, the clearance between the first row of terminal blocks shall be minimum of 100 mm.

xvii. EARTHING TERMINALS

Control panel shall have to separate earthing terminals suitable for necessary earthing conductors o size specified

xviii. CONTROL PANEL

a. Panel shall be cold rolled sheet steel enclosed, of thickness not less than 2.5 mm free standing, floor mounting, indoor type, dust and vermin tight, degree of protection IP – 54, with front accessibility having concealed hinged doors, with key locked and handles and bolted rear and side covers.

b. Ventilation louvers shall be at the side and /or back and shall be fitted with fine mesh screens to prevent entrance of rodents or large insects.

c. Foundation channel with nuts, bolts, spring washers, 3mm thick undrilled gland plate, cable gland shall be part of the supply.

d. Components mounted on the panel shall be flush type. Arrangement of components shall be such as t render easy accessibility for maintenance and troubleshooting.

e. Heating emitting components like resistors shall be shielded from others by fiber glass sheet separators or similar materials.

xix. MAINS OPERATED BATTERY CHARGING EQUIPMENT

a. The battery charger shall be of the static type employing semi -conductor devices, the whole being enclosed in an adequately ventilated enameled corrosion resistant sheet steel case of an approved type. This shall be part of relay & monitoring panel, mounted inside the same.

b. The charger shall be incorporated within the control panel with its associated instruments and controls mounted on the control panel. The instruments and controls shall match those of the main panel.

c. The charger shall have an illuminated indicator on the panel front to show when the charger is switched on. The charger shall be of adequate size and shall at all times monitor the battery conditions and automatically control the charging rte to suit the state of the battery, maintaining it in a properly charged condition when not in use. Following a period of use,

d. the charger shall automatically re-charge the battery in the shortest practicable time consistent with battery welfare and the size and output of the charger shall match battery size and shall at all times monitor the battery conditions the charging rate to maintain the state of the battery, maintaining it in a properly condition when not in use.

xx. PROTECTION

The diesel generator shall be tripped under the following conditions: -

a. 110V DC control supply failure.

b. Over-speed of diesel generator set

c. Low lube oil pressure

d. excitation failure.

e. Incomplete start after a present time.

f. High jacket water temperature.

g. DG differential protection.

h. Reverse power protection.

i. Earth fault protection.

j. Emergency stop.

xxi. ALARM AND INDICATIONS

Local Alarm on Panel:

The following alarms shall be included in the alarms and supervision system:

a. High jacket water temperature (As applicable)

b. Low lube oil pressure

c. Generator bearing temperature high.

d. Generator winding temperature high

e. Fuel oil day tank level low.

f. Fuel oil day tank level high.

g. 110V DC control supply failure.

h. Reverse power trip

i. Over current trip

j. DG earth fault.

k. Emergency stop.

l. Starting failure.

Local Lamp Indication on each Diesel Control Panel:

The following Meters shall be included in the Metering Chamber of the Panel

i 1 No. Ammeter with selector switch. (0 – 200A)

ii 1 No. Voltmeter with selector switch. (0 – 12KV)

iii 1 No. Frequency Meter.

iv 1 No. KW Meter

v 1 No. KVA Meter

vi 1 No. KWHr Meter

vii 1 No. P F Meter

viii 1 No. Trivector Meter

The Following Protection relays shall be included in the Relay Panel:

a. IDMT Three O/C + E/F relay with highest

b. Over / Under Voltage Relay.

c. Reverse Power Relay

d. Restricted Earth Fault Relay

e. Differential Relay

f. Auto Synchronizing Relay

g. Auto Load Sharing Relay

h. Thermal Overload

i. Over / Under Frequency

j. Loss of Field

k. PT Fuse Failure

The following Auxiliaries shall be included

a. 1 No. Multipoint Temperature Scanner for WTDs & BTDs.

b. 1 No. Motorized Potentiometer for speed / voltage, raise / low.

c. 1 Set of Indicating Lamps for Load ON DG & Load ON Mains.

d. 1 No. Emergency Push Button.

**o) FREE STANDING CHIMNEY**

Total Gas flow from 2 x 2000 KVA at portal: To be confirmed by vendor.

| | |
|---|---|
| Temp – deg. C | To be confirmed by vendor |
| Chimney material | : IS 2062 |
| Design code | : IS 6533 |
| Wind Load | : as per IS 875 (Part 3)-1987 |
| Earth Quake stability | : as per IS 1893 – 2002 |
| Foundation to be designed | : To withstand wind load and earthquake |
| Painting | : Anti corrosive black painting shall be carried out on the Inner surface of the chimney. Shall confirm to IS 158 – 1968. |

Note: The exhaust from the Generators shall be directly exhausted to atmosphere without any treatment. This requirement shall meet the norms of State Pollution Control Board.

**p) BATTERY AND BATTERY CHARGER**

i.BATTERY

Batteries – 25 Plate, 180 AH, heavy duty

Batteries shall be of lead acid type, heavy duty Automotive power mounted near the generator. A corrosion resistant battery rack shall be provided for mounting. Battery shall have sufficient capacity to provide for the engine/generator safety circuits, for 24 hours without recharging. The batteries shall be suitable for 6 successive attempts each of 10 secs duration with a gap of 5 sec forward starters. The battery bank shall be provided with steel stand and a containment tray. Also, a rubber mat shall be provided below the battery rack. Battery shall be confirming to IS: 1651.

ii.BATTERY CHARGER

a. A current limiting battery charger shall be provided to automatically recharge the batteries. Battery charger shall have boost and trickles charging features with built in voltage regulators. Battery Charger shall be suitable for operation on 230V AC, 50 Hz supply with variation of +/- 10%. The charger shall charge at 2.17 Volts per cell and float at 2.33 Volts per cell. It shall include overload protection, silicon diode full wave rectifiers, voltage surge suppressors, DC Ammeter, and fused AC input. The amperage output shall be not less than 10A. Each Generator shall be provided with separate battery charger.

b. The following indications shall be required:

Input supply on.

Battery charge/discharge current.

Output voltage.

c. Voltage free change-over contacts shall be wired to the outgoing terminal block of the unit to provide external indication of the following conditions:

Input AC supply fail.

d. The charger must be large enough to provide for a 100 percent increase in the charging needs of the batteries for future sets.

e. Battery charger with suitable cut-out circuit shall be provided for charging battery from EB mains when DG is not running. Suitable capacity dynamo shall be provided for charging the batteries when DG is in operation. A separate voltmeter and ammeter shall be provided for monitoring battery voltage and current.

f. CAPACITY

180 Ah 12 V - 4 Nos.

**q) ACOUSTIUC ENCLOSURE**

The acoustic enclosure is made of 1.6 mm thick CRCA sheets and structural/ sheet metal base frame painted in Munsell shade. The walls of the enclosure are insulated with fire retardant Rock wool.

The enclosure has the following features:

i. Designed to have optimum power out of Genset without any de-rating factor.

ii. Designed to have sufficient approach, operation and service space.

iii. Air inlet louvers specially designed to provide sufficient fresh air availability for operation of the D.G.set.

iv. Made on special purpose CNC machines for consistency in quality and workmanship

v. Powder coated for long lasting service life and superior finish

vi. With UV resistant powder coating, withstands extreme environments

vii. Use of special hardware for longer life

viii. Insulation material meets exacting IS 8183 specifications for better sound attenuation

ix. Flush styling - no projections

x. Fluid drains for lube oil.

**r) PROPELLER FANS**

Propeller fans shall have MS powder coated or epoxy coated diaphragm. The impellers shall be die cast aluminium or MS powder coated epoxy coated with adequate gauge sheet. The fans shall be statically and dynamically balanced. The fans shall be suitable for mounting vertically and should withstand higher temperatures. The fans shall be suitable for 3-phase operation as specified in the tender conditions. The vendor shall clearly determine whether propeller fans are required and confirm expressly at the time of tendering itself.

Note: Other than GI sheet of insulation works all other materials shall be powder coating.

**Axial Fans**

The tunnel axial fans shall be designed, manufactured and tested in accordance with the latest

revision of the following standards.

International Standards Organisation (ISO):

ISO 281 Rolling bearings: dynamic load ratings and rating life

ISO 1680 Test code for the measurement of airborne noise emitted by rotating electrical machinery: engineering method for free field conditions over a reflecting plane

ISO 5135 Noise: Air distribution and diffusion

ISO 8821 Mechanical vibration: balance. Balancing shaft and fitment key convention

ISO 117 Method of testing the performance of jet fans Underwriter's Laboratories. Inc. (UL):

508 Industrial Control Equipment.

The minimum design life for all equipment covered by this specification shall be 20 years.

**s) FUEL HANDLING SYSTEM**

i.DAY TANK (990 L Capacity)

a. The design and construction of the tank shall comply with:

- IS: 10987:1992 and the other complimentary and reference standards stated there in.
- Rules and Regulations of the Chief Inspector of Explosives
- India Petroleum Rules 1956.

b. All site welding shall be carried out by fusion welding. For all butt welds, the root run and final run shall be carried out.

c. The HSD tanks shall be of min 3 mm thick M S construction, horizontal, cylindrical in shape with plain ends and shall be suitable for storage of fuel up to a maximum temperature of 50 Deg C at atmospheric pressure. Tanks shall be painted externally to prevent corrosion and shall have a reflecting surface.

d. The external surface of the storage tanks shall be cleaved to remove rust, scale, etc. and apply two coat of zinc chromate anti-rust primer followed by two coats of finishing paint - epoxy paint.

e. The tank shall be designed for a pressure of 0.05 MPA when full of water. Minimum corrosion allowance of 1.5 mm shall be considered. The design temperature shall be the lowest one-day mean temperature where the tank is to be installed.

f. The following accessories shall be part of the tank:

- Filling point and drain off point
- Dip Connection
- Vent pipe
- Over flow pipe
- Drain-pipe
- Continuous Level gauge with dial type indicator on top of the tank.
- 550 mm dia manhole with cover and locking arrangement.
- High /Low level sensors
- Lifting lugs
- Painting with Anti corrosive treatment.
- Spill tray to be located below the tank and all around it
- Metal Support structure, wear plates, stiffeners etc

ii.PIPING

All fuel piping shall be minimum 25mm dia M.S Class B and as per IS: 1978 and IS: 2062. All fittings shall be of heavy duty. Flanges shall conform to ASA-Class 150 weld neck. The piping shall generally be installed in already prepared underground trenches with fixing hardware as required.

iii. VALVES

All valves shall be ball type and of cast steel body with gunmetal or stainless-steel ball only. All the valves shall be pressure tested as per ASA-class 150. The valves shall confirm to IS 10611, IS 11792.

**t) Inspection, Testing and Dispatch**

i. Inspection and testing shall be carried out based on this specification and with approved drawings certified by the consultant / Client. The Client and their consultants shall have the right to carry out stage inspection and shop visit to review the manufacturing progress. All routine and type tests specified shall be carried out during final inspection. 15 days advance notice shall be given for carrying out the final inspection.

ii. Any fuel charges for load testing shall be included in the offer, which shall be indicated separately in the Offer. Bidder shall ensure that a competent testing authority calibrates all meters and equipment used testing and the calibration certificates are valid at the time of carrying out test. After completion of inspection and testing Bidder shall furnish all as built.

iii. documents in two sets. Only on receipt of final documents the release order for dispatch of equipment shall be issued.

**u) DELIVERY AND HANDLING**

The engine/generator sets shall be delivered to site properly packaged and mounted on pallets or skids to facilitate handling of heavy items. Factory- fabricated type containers or wrappings shall be utilized for engine/generator and components, which shall protect equipment from damage. Engine-driven generator equipment shall be handled carefully to prevent physical damage to equipment and components. Any damaged equipment shall be removed from site and replaced with new equipment.

**v) INSTALLATION AND COMMISSIONING**

i. Installation & Commissioning shall be carried out based on the latest requirement of the various statutory authorities such electrical inspector, factory inspector, pollution control board, regulatory authority, and any other statutory agency appointed by the purpose by the state / central / municipal bodies. The document / drawings required for obtaining the approval shall be prepared by the bidder.

ii. The Bidder shall obtain the approval for the installation from all the above agencies. All official payment made for such approvals shall be reimbursed at actual on submission of original receipts.

iii. After installation as per the final approved drawing, the Bidder shall carry out the site testing as specified in presence of consultant. DG shall be taken over by Client only on acceptance by the consultant and satisfactory test results.

iv. The Employer shall witness the commissioning.

v. A minimum of seven working days' notice shall be given to the Consultant / Employer prior to the start of commissioning.

vi. A Specialist Agency approved by the Consultant / Employer shall be responsible for the testing and satisfactory performance of the complete synchronizing system.

**w) SITE REGULATIONS FOR INSTALLATION WORK**

i. Site discipline shall be observed by all the Bidders / erection Concessionaire's personnel inside the premises of the site. The Concessionaire and his personnel shall abide by all the rules and regulations laid down by the client. The Concessionaire shall be required to carry out the installation work simultaneously with other installation work being executed by other Concessionaires and shall extend all co-operation required.

ii. Electrical Power required for construction, installation and commissioning of DG shall be provided by the client at one point near meter location. The Bidder shall have his own cabling and switch gear for power distribution to his work place. Cabling and switchgear arrangement shall be provided in accordance with rules and regulation duly approved by the consultant.

iii. Purchaser/Client will not be responsible for any damages / compensation payable in case of any accident/injuries to any of the Concessionaire's personnel. In case of any accident at site in connection with the execution of work Concessionaire shall report the accident within 24 hours to the client. All transports of material to and from site shall be marked clearly and visibly and shall be accompanied by appropriate documents.

**x) SERVICE**

Manufacturers shall have established network of service centers capable of servicing the specified equipments. The Personnel shall be factory trained and shall be available for servicing

**y) PROPOSED LAYOUT**

The diesel generator units and their auxiliaries will be installed in the DG Building ground floor. Supplier shall recommend his layout and indicate space requirement. The DG sets will be arranged to draw air from outdoors. Exhaust will be discharged through a vertical mounted muffler into individual exhaust pipe.

Concessionaire shall indicate the number of air changes required for site conditions for safe operation of DG set. Manufacturer shall indicate the heat load to be removed from DG set room.

**z) Documentation and Testing**

The following documents, drawings etc shall be submitted along with the offer:

- Technical document of AVR, Governor, etc.
- Schematic diagram of engine control panel with accessories like AVR on details etc.
- Single line diagram for the whole system – control and power
- Detailed specification sheet for all auxiliary components giving material specifications, make / model, capacity, rating etc.
- Foundation details.

**aa) TESTING**

The following tests shall be carried out at the Bidders works for the assembled DG Set in presence of Consultants / Architects / Clients.

i. Routine tests shall be conducted in the presence of Client / Consultant at the factory before shipping by simulating faults to check the proper functioning of the Generators and Alternators.

ii. Load test using water load shall be carried out in the presence of Client / Consultant to prove the efficiency of the system.

iii. Alignment between engine and alternator by authorized representative from the company.

iv. Operational test for satisfactory functioning.

v. Relay tests – wherever applicable.

vi. Insulation resistance check on alternator and relay panel (if relay panel is supplied by DG vendor)

vii. TEST ON ENGINE

- 25% load for 1 hour.
- 50% load for 1 hour.
- 75% load for 1 hour.
- 100% load for 1 hour followed by 30 min. running at 110% of load

viii. TESTS ON CONTROL PANEL

- Insulation resistance test
- High voltage withstand test
- Functional and operation test
- Secondary injection test on meters & relays :
- Mechanical testing of components.

ix. SITE TESTING

(To be carried out by Bidder witnessed by Client if factory test is not conducted):

a. Load test for one hour at full load.

b. 100% load for 1 hour followed by 30 min. running at 110% of load AMF sequence checking with all interlocks in line. Measurement of starting time from cold condition.

c. Load will be provided by customer. Consumables (for excess of first fill) will be provided by the customer.

**bb) INSPECTION, OPERATION, MAINTENANCE MANUALS**

The bidder shall submit the type test and routine test certificates along with delivery of DG set. Bidder shall submit two sets of as built drawings, operation and maintenance manual, Spare parts manuals of all components duly certified by the consultants after installation.

**cc) AS BUILT DRAWINGS**

Bidder shall submit dimensional drawing showing location of all equipments inside the acoustic room housing the DG set and the cable route.

**dd) PRODUCT DATA SHEET**

Enclosed elsewhere in this document, vendors go through and provide inputs wherever necessary and confirm parameters asked for.

**ee) TRAINING**

The Employer 's technical team shall be trained in all aspects of operation, maintenance and administration of the system

**ff) STATUTORY CLEARANCES**

The Bidder will be responsible for the statutory clearances from the electrical inspector, pollution control board (lab report), regulatory authority, and any other statutory agency appointed for the purpose by the state / central / municipal bodies. The documents / drawings required for obtaining the approval shall be prepared by the bidder.

**gg) SPECIAL NOTES**

Major civil works like RCC foundation etc in not included in the scope. However, All other works and materials, tools, tackles, hardware, consumables, fuel, oil etc. including grouting of the foundation bolts, metal support structure, scaffolding as required and necessary hardware to complete and commission the installation is deemed as included in the offer unless specifically stated and agreed to by the Client before the placement of order.

The Bidder shall be responsible for providing foundation drawings and load calculation to the Consultant / Client for making necessary foundations.

**hh) ENERGY CONSERVATION APPLICATIONS**

Please furnish the various methods that have been adopted in the engine, alternator and fuel systems to produce maximum energy per litre of diesel consumed with statistical data's.

**ii) SPECIFIC REQUIREMENTS**

A. NOISE LIMIT FOR GENERATOR SETS RUN WITH DIESEL

a. Noise limits for diesel generator sets, shall be as follows:

b. Noise from DG set shall be controlled by providing an acoustic enclosure or by treating the room acoustically, at the users end.

c. The acoustic enclosure or acoustic treatment of the room shall be designed for minimum 25 dB (A) insertion loss or for meeting the ambient noise standards, whichever is on the higher side (if the actual ambient noise is on the higher side, it may not be possible to check the performance of the acoustic enclosure/acoustic treatment. Under such circumstances the performance may be checked for noise reduction upto actual ambient noise level, preferably, in the night time). The measurement for Insertion Loss may be done at different points at 0.5 m from the acoustic enclosure/room, and then averaged.

d. The DG set shall be provided with proper exhaust muffler with insertion loss of minimum 25 dB(A).

e. These limits shall be regulated by the State Pollution Control Boards and the State Pollution Control Committees.

B. Guidelines for the manufacturers/users of Diesel Generator sets shall be as under:

a. The manufacturer shall offer to the user a standard acoustic enclosure of 25 dB(A) insertion loss and a suitable exhaust muffler with insertion loss of 25 dB(A).

b. The user shall make efforts to bring down the noise levels due to the DG set, outside his premises, within the ambient noise requirements by proper siting and control measures.

c. Installation of a DG set must be strictly in compliance with the recommendations of the DG set manufacturer.

d. A proper routine and preventive maintenance procedure for the DG set should be set and followed in consultation with the DG set manufacturer which would help prevent noise levels of the DG set from deteriorating with use.

C. REQUIREMENT OF CERTIFICATION

Every manufacturer or importer (herein after referred to as "supplier") of DG set (herein after referred to as "product") to which these regulations apply must have valid certificates of Type Approval and also valid certificates of Conformity of Production for each year, for all the product models being manufactured or imported from 1st July, 2003 with the noise limit specified in paragraph above.

D. SALE, IMPORT OR USE OF DG SETS NOT COMPLYING WITH THE RULES PROHIBITED

No person shall sell, import or use of a product model, which is not having a valid Type Approval certificate and Conformity of Production certificate.

E. NODAL AGENCY

- The Central Pollution Control Board shall he the nodal agency for implementation of these regulations.
- In case of any dispute or difficulty in implementation of these regulations, the matter shall be referred to the nodal agency.
- The nodal agency shall constitute a Committee to advise it on all matters; including the disputed matters, related to the implementation of these regulations.

F. AUTHORIZED AGENCIES FOR CERTIFICATION

The following agencies are authorized to carry out such tests as they deem necessary for giving certificates for Type Approval and Conformity of Production testings of DG sets and to give such certificates: -

- Automotive Research Association of India, Pune
- National Physical Laboratory, New Delhi
- Naval Science & Technology Laboratory, Visakhapatnam
- Fluid Control Research Institute, Palghat
- National Aerospace Laboratory, Bangalore

G. COMPLIANCE AND TESTING PROCEDURE

The compliance and testing procedure shall be prepared and published by the Central Pollution Control Board, with the help of the certification agencies.

H. Emission standards for diesel engines (engine rating more than 0.8mw (800kw) for power plant generator set applications and other requirements

1. EMISSION LIMITS

The emission limits for new diesel engines more than 800 kw, for gensets applications shall be as given in the Table below:

| Parameter | Area Category | Total engine rating of the Plant (includes existing as | Generator sets commissioning date | | |
|---|---|---|---|---|---|
| | | | Before 1/7/2003 | Between 1/7/2003 And | On or after 1/7/20 05 |

| | | | | | | |
|---|---|---|---|---|---|---|
| | | | well as new generators sets) | | 1/7/2003 | |
| Nox(as NO2)(AT 15% O2), dry basis, in ppmv | | A | Upto 75MW | 1100 | 970 | 710 |
| | | B | Upto 150MW | | | |
| | | A | More than 75MW | 1100 | 710 | 360 |
| | | B | More than 150MW | | | |
| NMHC (as C) (at 15% O2), mg/$Nm^3$ | | Both A & B | | 150 | 100 | |
| PM (at 15% O2), mg/$Nm^3$ | Diesel Fuels-HSD & LDO | Both A & B | | 75 | 75 | |
| | Furnace Oils-LSHS & FO | Both A & B | | 150 | 100 | |
| CO (at $_{mg/Nm^{15\%O2}}$3), | | Both A & B | | < 2% | | |
| Sulphur content in fuel | | A | | < 4% | | |
| | | B | | | | |
| Fuel specification | | For A only | Up to 5MW | Only Diesel Fuels (HSD,LDO) shall be used | | |

| | |
|---|---|
| Stack height ( for generators sets commissioned after 1/7/2003) | Stack height shall be maximum of the following, in meter:<br>i. $14\ Q^{0.3}$, Q = Total SO2 emission from the plant in kg/hr.<br>ii. Minimum 6m above the building where generator set is installed.<br>iii. 30 m. |

2. Applicability

These rules shall apply to all new diesel engines for genset applications (herein after referred to as 'engine') manufactured in India and all diesel engines for genset applications and diesel gensets (herein after referred to as 'product'), imported into India, after the effective date: Provided that these rules shall not apply to:

- Any engine manufactured or engine or product imported for the outside India, or; purpose of export
- Any engine or product intended for the purpose of sample only and not for sale in India.

3. Requirement of Certification

Every manufacturer of engine or every importer of engine or product must have valid certificates of Type. Approval and certificates of Conformity of Production for each year, for all engine models being manufactured or for all engine or product models being imported, after the effective date with the emission limit as specified in paragraph 1.

4. Requirement of Conformance Labeling

a. All the engines (individually or as part of the product) shall be clearly engraved 'Genset Engine' on the cylinder block.

b. The engine or the product must be affixed with a conformance label meeting the following requirements: -

- The label shall be durable and legible;
- The label shall be affixed on a part necessary for normal operation of the engine or the product and not normally requiring replacement during the life of the engine or the product.

c. The conformance label must contain the following information:

- Name and address of the engine manufacturer or the engine or product importer (if the address is given in the owner's manual, it may not be included in the label);
- Statement that 'this engine or product conforms to the Environment (protection) Rules, 1986';
- Type approval certificate number;
- Date of manufacture of engine or in case of import, the date of import of the engine or the product.

5. Compliance with BIS Specifications

All engines up to 20 kw (individually or as part of the product) shall carry ISI mark and meet relevant BIS specifications (IS 1000 1).

6. Nodal Agency

The Central Pollution Control Board shall be the, nodal agency for implementation of these rules.

In case of any dispute or difficulty in implementation of these rules the matter shall be referred to the nodal agency.

The nodal agency shall constitute a Committee to advise it on all matters, including the disputed matters, related to the implementation of these rules.

**jj) AUTHORISED AGENCIES FOR CERTIFICATION**

The following agencies are authorized to carry out such tests as they deem necessary for giving certificates of Type, Approval and Conformity of Production tests for Diesel engines and to give such certificates: -

Automotive Research Association of India

**kk) AUTHORISED AGENCIES FOR CERTIFICATION**

The compliance and testing procedure shall be prepared and published by the Central Pollution Control Board with the help of the Certification Agencies.

**ll) FUEL SPECIFICATION**

The specification of commercial fuel applicable for -diesel gensets shall be the same as applicable for commercial HSD (High Speed Diesel) applicable for diesel vehicles in the area, from time to time."

Bidder shall submit dimensional drawing showing location of all equipments inside the acoustic room enclosure housing the DG sets. The hard and soft copy of proposed DG set is to be enclosed with foundation details.

### 7.2.5 HT Cables & LT Cables

**1. Scope**

This specification covers the technical requirements of design, manufacture, test at manufacturer's works, packing & forwarding, supply, storage, and erection of HT & LT cables.

**2. GENERAL**

a. This specification covers the technical requirements of design, manufacture, test at manufacturer's works, packing & forwarding, supply, storage and erection of HT & LT cables.

b. Principally all cables shall consist of one length. Connecting sleeves / joints are not allowed, except, the connection points are allowed by the Independent Engineer.

c. For energy cables the cable dimensioning shall be in accordance with the relevant standards, and shall have a diameter assuring, that voltage drop is not more than 10 % to the nominal voltage from the transformer to the most distant supplied electrical facility.

d. The cables shall also have such diameters that, if there is a short circuit at the furthest point to the circuit breaker, the circuit breaker cuts off efficiently without exceeding the cable's rated temperature rise.

e. Cables shall be brought to the site on cable reels or cable drums and shall be secured with close- fitting battens. Cables with kinks or abrasions will not be accepted for installation.

f. The installation of the cables is only allowed in / at the required cable routes. The Concessionaire shall be fully responsible for the protection of the cables against damage while they are stored, installed, or worked with.

g. The Concessionaire shall give complete information of all cables to the engineer for his approval.

h. All cables shall be installed generally along the routes and in the manner indicated on the drawings in accordance with the notes and instructions thereon.

i. Sufficient and adequate apparatus and equipment necessary for the unloading, handling, transportation and installation of the cables shall be provided by the Concessionaire at his own expense, the apparatus and equipment must not be removed from the site without the authorization of the engineer.

j. The Concessionaire shall take all necessary precautions to prevent damage to cables during laying / installation.

k. Whenever cables are installed during other work at this site still being incomplete, the Concessionaire shall take all reasonable precautions to protect the cables against damage arising from the execution of other works.

l. All cables shall directly run from point to point without joints unless the needed cable length required is not obtainable in one piece from the cable manufacturers. In such a case, the engineer has to approve the position of each and every joint. No other joints shall be permitted unless they are specifically called for in this specification or at the drawings.

m. Where a cable shall change direction, whether horizontal or vertical, the radius of the bend must not be less than the minimum bending radius specified in the IEE Wiring Regulations and / or the cable manufacturer's specifications. So the bending radius of the cables shall be kept as large as possible.

n. Wherever a cable is cut, for whatever reason, the ends of both portions shall be immediately re- sealed. Cables shall be sealed by means of an approved plastic cap embracing the armour wires and outer sheath. No other form of temporary capping shall be accepted.

## 3. APPLICABLE STANDARDS

The equipment shall conform to latest relevant applicable Indian Standards. Equipment's complying with any authoritative standards such as British, U.S.A., V.D.E. IEC etc. will also be considered if it assures performance equivalent to or superior to standards listed below. In such cases, bidder shall clearly indicate the latest standard / standards adopted and furnish a copy of the English version / translation of the same. Should there be any dispute of design, standard the most stringent shall be followed: -

| | |
|---|---|
| IS-8130 | Conductor for insulated electric cables & flexible cords |
| IS-398(Part-IV)/1994 | Aluminum Alloy Conductors |
| IS-5831 | PVC insulation and sheath of electric cables |
| IS-7098 (Part-II) | Cross-linked polyethylene insulated thermoplastic sheathed Cables (Part-II) |
| IS-5216 | Guide for safety procedures and practices in electric works |
| IEC-228 | Conductor for insulated cables |
| IEC-502 | Extruded solid dielectric insulated power cables for rated Voltages from 1 KV up to 30 KV |
| IEC-540 | Test methods for insulations and sheaths of electric cables and cords. |
| NFPA 502 | Standard for Road Tunnels, Bridges, and other limited Access Highways |
| IS-3975 | Mild steel wires strips and tapes for armoring cables |
| BS-5468 | Cross-linked polyethylene insulation of electric cables |
| IEC-840 | Test for power cables with extruded insulation |

Indian Electricity Rules

Indian Electricity Act

The Electricity Act 2003

The design, manufacture and performance of the equipment and services provided under this specification shall comply with the standards, rules, regulations and acts given in this specification.

## 4. HT Power Cables

### a. GENERAL TECHNICAL REQUIREMENTS:

This specification covers Design, Engineering, Manufacturing, Testing, packing at manufacturer's works and Delivery of 11 KV (E), FRLS, PVC Insulated, XLPE insulated, galvanized steel flat wire armoured cable.

All cables shall be suitable for installation in air, conduits, ducts; open concrete trenches, for direct burial in either wet, or dry locations for normal operating conditions.

### b. GENERAL CONSTRUCTIONS:

The cross-linked polyethylene insulated (XLPE) Cable shall be manufactured and tested strictly in accordance with the Indian Standard IS 7098 (Part – II) and its latest amendments.

All material used in the manufacturing of cables shall be new and shall be selected as the best available for the intended use.

### c. CONDUCTORS

All conductors shall be of stranded construction complying with the requirement of class II of IS: 8130 with latest amendments. A conductor filling (strand blocking) is required to inhibit water migration along the conductor. This material may be viscous semi conductive liquid or swelling powder and capable of 90 degree Celsius continuous operation. The filling material shall be compatible with the semi conducting & insulating compounds in the cable. In addition, the filling shall have zero flow & no drip at temperature below 90 degree Celsius and it must not harm the electrical conductivity of the conductor or joint. The supplier shall describe the method of preparing the filled central conductor for jointing.

All conductors shall be of high electrical conductivity Aluminium conforming to requirement of IS: 8130 with latest amendments.

Before stranding, the conductor shall be circular in cross section, uniform in quality, solid, smooth and free from scale, sharp edges and other defects.

**d. CONDUCTOR SCREEN**

Conductor screening shall consist of a layer of extruded semi-conducting compound as per IS – 7098 (Part-II) with latest amendments.

The semi-conducting compound shall be suitable for the operating temperature of the cable and compatible with the insulating material.

**e. INSULATION**

The insulating material shall be Cross Linked Polyethylene (XLPE) as per IS-7098 and its latest amendments. The insulation shall be an extrusion cross linked polyethylene fire retardant material rated for 90-degree Celsius continuous operation.

The insulation properties shall be stable under thermal conditions arising out of continuous operation at conductor temperature of 90 degree Centigrade rising momentarily to 250 Degree Centigrade under short circuit conditions.

It shall be free from any foreign material or porosity visible to the unaided eye. The insulation shall be so applied that it fits closely on the conductor and it shall be possible to remove it without damaging the conductor.

The average thickness of insulation shall not be less than the nominal value as specified in IS: 7098 (Part II) with latest amendments. No tolerance on the negative side shall be acceptable.

The insulating material shall have excellent electrical properties with regard to resistivity, dielectric constant and loss factor and shall have high tensile strength and resistance to abrasion. This shall not deteriorate at elevated temperatures or when immersed in water. The insulation shall be preferably fire resistant and resistant to chemicals like acids, alkalies, oils and ozone.

**f. INSULATION SCREEN:**

Extruded Semi-conducting screening and metallic screening of copper tape shall be generally as per IS: 7098 (Part-II) with latest amendments.

The semi conducting compound shall be suitable for the operating temperature of the cable and compatible with the insulating material.

**g. CORE IDENTIFICATION:**

Individual core of multi-core cables shall be colour coded and/or numbered for proper identification in accordance with the IS: 7098 (Part – II).

**h. LAYING UP OF CORES:**

In three core cables, the cores shall be laid together with a suitable right hand lay. The interstices shall be filled with non-hygroscopic material.

Further, the compounds used with fillers shall be such as to have no deleterious effect on other components of the cable and to be stable at cable temperatures.

**i. INNER SHEATH:**

The laid-up cores shall be provided with inner sheath applied by extrusion process. It shall be ensured that the shape is as circular as possible. It shall be applied to fit closely on to the laid-up cores and shall be possible to remove easily without causing any damage to the underlying insulated cores and screens.

The thickness of the inner sheath shall be as per IS: 7098 (Part - II). No tolerance on the negative side shall be acceptable.

**j. ARMOURING**:

The armouring shall be of galvanized steel flat wires for multi core cables. The armouring shall be applied as closely as practical. The galvanized steel wires shall comply with the requirements of IS: 3975 with latest amendments. The dimensions of the galvanized steel wire shall be as per IS: 7098 (Part-II). No tolerance on the negative side shall be acceptable.

**k. OUTER SHEATH:**

The outer sheath shall be of polyvinyl chloride (PVC) compound conforming to the requirements of Type ST 2 of IS: 5831 with latest amendments. The outer sheath shall be applied by extrusion process.

The thickness of the outer sheath shall be as per IS: 7098 (Part - II). No tolerance on the negative side shall be acceptable.

- PACKING:

Cables shall be furnished in the specified lengths. Drums (wooden or steel as specified) shall be strong, weatherproof, and non-returnable. Wooden drums shall be as per IS 10418-1982 and its latest amendments. The ends of the cable shall be suitably sealed by means of non-hygroscopic sealing material.

**5. LT Power Cables - 1.1kV grade, Copper conductor, Power cables**

**a. Scope**

This section covers the technical specifications for design, engineering, manufacturing, inspection, testing at manufacturer's works, packaging, and delivery by road (properly packed in non-returnable steel drums), 1.1KV grade, Multi-stranded Copper conductor, XLPE insulated, extruded PVC inner sheathed, GI round-wire armoured, extruded FRLS PVC ST2 outer sheathed. Power Cables for effectively grounded system, conforming to the latest revisions of IS: 7098 (Part –I), 1988 & as per the technical specifications given below.

**b. STANDARDS**

The design, manufacture and testing of the cable shall comply with the latest editions/amendments of the following Indian Standards, unless otherwise specified. Equipment complying with equivalent standards shall also be acceptable.

| | | |
|---|---|---|
| a) | IS-7098, 1998 (Part-I) | Cross linked polyethylene insulated PVC sheathed cables for working voltages upto 1100V. |
| b) | IS-3961 | Recommended current ratings for cables |
| c) | IS 8130-1984 | Specification for conductors insulated electric cables and flexible cords. |
| d) | IS-3975, 1999 | Low Carbon galvanized steel wires, formed wires & tapes for armouring of cables |
| e) | IS-4759 | Specifications for Hot dipped galvanized coating on round steel wires |
| f) | IS-5831 | PVC insulation and sheath of electric cables |
| g) | IS-10418 | Drums for electric cables. |
| h) | IS-10810(Part 0 to 64) | Method of test for cables. |

**c. SERVICE CONDITION**

The cable shall be designed with the following service conditions into consideration:

i. Cables shall be capable of satisfactory operation under a power supply system frequency variation of +3% and voltage variation of ±10%.

ii. Cables shall be suitable for laying in conduits, ducts, trenches, channels, trays, racks or for direct buried in ground in both dry and wet locations with chances of flooding by water.

iii. The cables shall be suitable for the following ambient condition:

Ambient Air temperature: -15 deg C to +30 deg C

Ambient ground temperature: 30 deg C

iv. The current rating shall be based on maximum conductor temperature depending on the type of insulation for continuous at the rated current.

v. The one second short circuit current rating values shall be furnished and shall be subjected to the purchaser's approval.

vi. The cables will have current ratings and de-rating factors as per relevant.

vii. Indian Standards.

Full technical details and descriptive literature shall be furnished indicating the construction details, standard applicable for the components of the cable and current ratings of the cables in air and ground. De-rating factors to be considered for the ambient temperature, ground temperature, de-rating due to cable location in air and ground shall also be furnished. The certificates for the type tests conducted on cables similar to the cables covered herein shall be submitted along with the tender.

**d. DESIGN AND CONSTRUCTION PARTICULARS**

i. General

The cables supplied under this specification shall be adequate insulated to operate continuously at the specified voltage with a high degree of safety and reliability throughout the life of the cables. The sheathing material shall be high quality PVC based compound. The construction of cable shall be as per IS: 7098 (Part I) - 1988.

Cable shall be designed and manufactured to prevent damage during transportation, installation & operation under all climatic & operating conditions to which cable may be subjected to.

**Table 8: TECHNICAL PARAMETERS OF 1.1kV XLPE CABLES**

| | | |
|---|---|---|
| i. | Quantity | As per BOQ |
| ii. | Packaging | Steel drum packaging, each having single length cable ≥ 500 metres. |
| iii. | Cable Type | A2XWY/ 2XWY |
| iv. | No. of Cores | 3/3.5/4 |
| v. | Voltage Level | 1.1kV |
| vi. | System Grounding | Solidly Grounded |
| vii. | Nominal System voltage | 400V ±10% |
| viii. | Nominal System Frequency | 50Hz ±3% |
| ix. | Maximum conductor temperature at rated current | 90°C |
| x. | Maximum conductor temperature | 250°C |

| | | |
|---|---|---|
| | at Short-circuit | |
| xi. | Conductor | |
| | Conductor Material | Electrolytic grade Copper, Purity > 99.97% |
| | Conductor type | Stranded with number of strands as per IS 8130 (Part-I) 1984 |
| xii. | Insulating material | Cross-Linked-Polyethylene (XLPE) Compound |
| xiii. | Core Identification Strips | Red, Yellow, Blue & Black (for neutral) |
| xiv. | Material of Inner Sheath | FRLS, PVC ST-2 Compound |
| xv. | Armour | Single layer of Galvanized Steel Round Wire according to IS-3975 |
| xvi. | Outer Sheath | FRLS, PVC ST-2 Compound according to IS-5831 |

ii.Conductor

- Copper:

The conductors shall be made from high conductivity copper rods complying with IS: 613-1964. The conductor material used shall be electrolytic grade with high purity. Two sample conductor randomly selected from finished lot of cables, shall be tested for its purity at any 3rd party NABL accredited lab.

- Cable Joints:

Joints shall be permitted in the individual wires of which the conductor is formed, but no joint shall be within 300 mm of any other joint within the same layer. The joints shall be made by resistance butt welding, fusion welding, cold pressure welding, electric welding, gas welding, brazing or silver soldering. No joint is allowed in the conductor after stranding. A maximum of two joint shall be allowed in any strand forming complete length of the cable.

The conductors shall conform to appropriate dimensions, resistance and number of wire in the conductor (number of strands) as given in IS 8130 (Part I): 1984.

iii.Insulation

The insulating material for power cables shall be extruded cross linked polyethylene (XLPE) compound as per IS-7098(Part-I)-1988. The minimum thickness of insulation shall not be less than the values specified in Table-2 of IS-7098 (Part-I)-1988. No negative tolerance shall be applicable for the thickness. The insulation of the cable shall be designed and manufactured for the specified system voltage. The manufacturing process shall ensure that insulation shall be free from voids. The insulation shall withstand mechanical and thermal stress under steady state and transient operating conditions. The cores shall be identified as per the following colour scheme:

3-Core - Red, Yellow & Blue

3 ½ or 4-Core - Red, Yellow, Blue & Black

iv.Inner Sheath

The inner sheath shall be extruded FRLS PVC, Type ST2, compatible with thermal rating of insulation conforming to IS-6380-1984. The sheath shall have adequate thickness, mechanical strength and elasticity, as specified in IS 5831. The material shall be soft thermoplastic type, applied by extrusion method. The thickness of the inner sheath shall be as per IS: 7098 (Part I) and the color of the inner sheath shall be Grey. The inner sheath shall be so formed that it fits closely on the laid up cores and could be easily removed without damaging insulation. One or more layer of proofed plastic tape shall be provided over the laid up core before extrusion.

v. Armouring

The armouring arranged over the inner sheath shall consist of one layer of galvanized round steel wires for all sizes of cable. The armour round wire used on the cable shall conform to IS: 3975 for all requirements. The direction of lay of armour shall be opposite to that of the cores. The zinc coating on the galvanized steel strip shall comply with relevant standards.

The joints in armour wires/strips shall be made by brazing or welding and the surface irregularities shall be removed. A joint in any wire/strip shall be at least 300 mm away from the nearest joint in any other wire/strip in the completed cable.

vi. Outer Sheath

Extruded outer sheath shall be provided over the armouring. The material used for sheathing shall be FRLS PVC sheath, Type ST-2 base compound conforming to IS 1554/ IS 5831 for power cable. The outer sheath shall be so formed that it fits closely on the laid-up armour and could be easily removed without damaging the intermediate sheath and insulation. The colour of the outer sheath shall be black. The thickness of outer sheath shall be in accordance with the IS 1554 (Part-I)-1988. Suitable additives shall be added to prevent attack by rodents and termites. All serving must be given anti-termite treatment.

Cables shall have suitable fillers laid up with the conductor to provide a substantially circular cross section before the sheath is applied. Fillers shall be suitable for the temperature of the cable and compatible with the insulating material. The material shall be of the best quality and workmanship. The fillers and sheath material shall be non-hygroscopic. All materials shall be new, unused and of the finest quality.

**e. TESTS**

All the tests specified below shall be carried out in accordance with the Indian Standards by the manufacturer in the presence of Purchaser's representative. If the cable fails to pass the test specified, the Purchaser shall have the option to reject it. Shipping release shall be obtained from the Purchaser's representative. The Purchaser, however reserves the right to waive off the inspection.

The tests at works shall include electrical, mechanical and hydraulic tests in accordance with the appropriate clauses of Statutory Regulation, relevant codes and standards, in addition any test called for by the Purchaser or his representative to ensure that the equipment being supplied fulfils the requirement of the specification.

For test not covered by any code or specifically mentioned in this specification, the test procedures are to be agreed with the Purchaser.

**f. Pre-Dispatch Inspection:**

i. The manufacturer shall be given at least 15 days advance notice prior to the commencement of testing, so that Purchaser's representative can plan to witness the tests.

ii. All the tests indicated in the test clause of this specification shall be carried out in the presence of Purchaser's representative by the manufacturer and shall provide all the facilities and equipment for testing.

iii. Six copies of the Test Certificate shall be furnished to the Purchaser for approval prior to dispatch of cables from factory.

iv. Visual check to conform the details given in this specification is to be done. In addition to the above, the general workmanship of the cable drums and cables laid in drums shall be checked.

v. Manufacturer shall have proper test set up for testing all the routine tests & type tests on finished cables as per IEC.

**g. Type Test**

Type tests on four randomly selected cable drums will have to be conducted in the presence of the department's representative. The test samples will be taken from finished cables. This test shall be in accordance to IS: 7098, Part-1,1988.

i.Test on Conductor

- Annealing test for copper conductors
- Tensile test for aluminium conductor
- Wrapping test for aluminium conductor
- Conductor Resistance Test

ii.Test on Insulation

- Physical dimension measurement
- Tensile strength and elongation at break
- Hot set test
- Shrinkage test
- Ageing in air oven
- Water absorption test

iii.Test on round Armour

- Physical dimension measurement
- Tensile strength
- Elongation at break
- Torsion test for round wires
- Winding test for firmed wire
- Mass of zinc coating.
- Uniformity of zinc coating
- Resistivity measurement, Resistance test for armour

iv.Test on Sheath

- Physical dimension measurement
- Tensile strength & Elongation at break test
- Ageing in air oven
- Loss of mass in air oven
- Shrinkage test
- Hot deformation test
- Heat shock test
- Thermal stability test

v.Insulation Resistance Test

vi.High Voltage Test at room temperature

vii.Volume resistivity at room temperature & at 90o C. (IS-10810-Part 43)

viii.Flammability test

ix.Test requirement of FRLS inner and outer sheath

The inner and outer sheath of cables shall meet the following test requirements related to flame retardant, low smoke emission, low acid and toxic gas emission. The BIDDERs shall have proper test apparatus to conduct all the relevant tests as per the applicable standards:

x.Flame retardant test on single cable

xi.Oxygen Index Test

The critical oxygen index value shall be minimum 29 when tested at 27+2ºC as per ASTMD-2863

xii. Temperature index test

Temperature index value shall be minimum 250ºC at oxygen index of 21 when tested as per NES 715.

xiii. Smoke Density Test

The cables shall satisfy the tests conducted to evaluate the percentage obscuration by smoke in an optical system placed in the path of the smoke. The maximum smoke density rating shall not be more than 60% when tested as per ASTM-D-2843.

xiv. Acid Gas Generation test (halogen acid gas evolution)

The hydrochloric acid generation when tested as per IEC 754-1 shall be less than 20% by weight.

xv. Test for specific optical density of smoke

xvi. Anti termite and rodent property test

The sequence of electric tests shall be as per the relevant Indian/International standards. The Bidder shall submit the sequence of tests for the approval of the purchaser before conducting the tests. A copy of the adopted standard shall also be supplied.

xvii. Routine Test (On each drum)

The following routine tests shall be carried out by the Manufacturer on each and every length of the cable in the presence of Purchaser's representative at manufacturer's works.

- Resistance test for conductors
- Insulation resistance test
- High voltage test

xviii. Conductor purity test

Two samples of copper shall be taken from any of the finished set of cables at random and the sample shall be tested for its purity at a NABL accredited lab.

xix. Qualifying Criteria:

The test results should be within limits as per IS 7098. All the routine tests as per IS 7098 / IEC shall be conducted and passed as per the limits given in the standards. All the bought-out certificates will be verified and the test results shall be as per respective standards.

**h. IDENTIFICATION**

The following details shall be marked sequentially for each meter run length of the cable by non-erasable embossing on the outer sheath:

- Reference to Indian Standard
- Name of the manufacturer/ Trade Name
- Name of the project: CWMF, BARC (K)
- Configuration of the cable: viz. Voltage grade, no. of Core, Sq. mm, A2XWY/2XWY/YWY / YY as applicable
- Year of manufacturing
- Sequential marking of running meter length

The running length of the cable shall be identified at regular intervals of one meter (Increasing order from inner end to outer end of the cable)

**i. PACKAGING**

- Each drum shall consist of single length cable ≥ 500 metres.
- The cable shall be wound on non-returnable steel drums of suitable size, packed and marked.

- Packing shall be sturdy to protect the cable from any injury during transportation, handling and storage. The cut ends of the cable shall be sealed by means of non-hygroscopic sealing material preferably Heat shrinkable end caps.
- One end of the cable shall be brought out of the drum and suitably clamped to the drum flange with proper mechanical protection. Location of the other end may be marked on the drum.
- The cable shall be placed on drums in such a manner that it will be protected from injury during transit. Each end of the cable shall be firmly and properly secured to the drum. No undue stress shall appear on cables when laid on drums.
- The cable drum shall carry the following information stenciled on a metallic label, securely attached to each end of the drum:

Reference to the Indian standard

Manufacturer's name, brand or trade mark

Type of cable and voltage grade

No. of cores

Nominal cross-sectional area of conductor

Cable code

Length of cable on drum

No. of lengths on reel, drum or coil (if more than one)

Gross weight

Country of manufacture

Year of manufacture

Direction of rotation of drum (an arrow)

ISI certification mark

**j. GUARANTEE**

All the cables shall be guaranteed against faulty material, defective design & poor workmanship for a period of 18 months from the date of supply. The materials becoming defective during the guarantee period shall be replaced free of cost and the defects arising out of the works shall be rectified free of charge without delay.

**6. Fire Survival Cables/Control Cables**

The cables shall be multicore, colour coded, annealed stranded high conductivity copper, single conductor, insulated with PVC insulation, PVC sheathed, conforming to IS / relevant IEC standards.

**Table 9: TECHNICAL PARTICULARS OF FIRE SURVIVAL CABLE**

| | | | |
|---|---|---|---|
| 1.0 | | Type of Cable | EPR INSULATED FIRE SURVIVAL CABLES |
| | | | |
| 2.0 | | Standard applicable in general (Latest amendment to be referred if any) | IS-9968(PART-1), IS-6380, IS -10810,IS 10418, IS-3975, ASTMD:2843, ASTMD-2863, IEC-60754-1, IEC-60331-1, IEC- |
| | | | |
| 3.0 | | Voltage Grade | 1.1 KV |
| | | | |
| 4.0 | | Number of cores, cross sectional area | As per BOQ-Cum-Price Schedule |
| | | | |
| 5.0 | | | |
| (a) | | Material | Copper |

| | | | |
|---|---|---|---|
| | | Grade and Class | Stranded, Tinned annealed high conductivity, Class 2 |
| (b) | | Standard Applicable | IS : 8130 |
| (c) | | Shape | Compacted circular / Shaped |
| (d) | | Min. number and diameter of strands | As per class -2 of IS 8130 |
| (e) | | Fire Barrier tape (separator tape) | Glass Mica tape in two layers with minimum 50% overlap |
| | | | |
| 6.0 | | **INSULATION** | |
| (a) | | Material | Heat resistant Elastomer compound , type IE2 |
| (b) | | Standard Applicable | IS : 9968(Part-1) IS : 6380 |
| (c) | | Continuous withstand | 90°C |
| (d) | | Short circuit | 250°C |
| (e) | | Method of application | By extrusion; sleeve extrusion not permitted |
| (f) | | Method of curing | Dry/Steam/Gas/Sioplas |
| (g) | | Nominal Thickness of insulation | As per IS : 9968(Part-1) |
| (h) | | Fire proof tape | Two Layers of plain Glass Fibre Binder Tape |
| | | | |
| 7.0 | | **CORE IDENTIFICATION** | Colour coding as per IS : 9968(Part-1) |
| 8.0 | | **INNER SHEATH** | |
| (a) | | Material | Heat resistant, oil resistant , flame retardant (HOFR) Elastomer compound |
| (b) | | Grade and type | Extruded Type SE-3 |
| (c) | | Standard Applicable | IS : 9968(Part-1) |
| (d) | | Colour | Black |
| | | | |
| 9.0 | | **ARMOUR** | |
| (a) | | Material: | |
| (i) | | Single core cables | Single layer of Hard Drawn Aluminium Round Wire of H4 grade |
| | | Standard Applicable | IS 8130 |
| (ii) | | Multi-core cables | Galvanised Steel Round Wire / Galvanised Steel Formed Wire |
| | | Standard Applicable | IS 3075 |
| (b) | | Gap between armour wires | Shall not exceed one armour wire space |
| (c) | | Minimum Coverage | 90% |
| (d) | | Breaking load of joint | 95 % of normal armour |
| | | | Zinc rich paint shall be applied on armour joint surface of GS |
| | | | |
| 10.0 | | **OUTERSHEATH** | |
| (a) | | Material | Heat resistant, oil resistant , flame retardant (HOFR) Elastomer compound |
| (b) | | Grade and type | Extruded Type SE-3 |
| (c) | | Colour | Black |

| | | | |
|---|---|---|---|
| (d) | | Marking | Cable size (cross section area and no. of cores) and voltage grade, IS 9968-Part II @ 5m (by embossing)<br>Word "EPR" "FS" etc, @ 5m (by embossing)<br>Manufacturer's name and/ or trade name, and year of manufacture @ 5m (by embossing)<br>'NFR and 'CUSTOMER' Name @5m (by |
| | | | |
| 11.0 | | **HOFR** | |
| (a) | | Oxygen index | >30 (as per ASTMD 2863) |
| (b) | | Temperature Index | >350ºC (as per ASTMD 2863) |
| (c) | | Acid gas generation | < 2% by weight (as per IEC 60754-1) |
| (d) | | Smoke density rating | < 20% (As per ASTMD 2843) |
| (e) | | Water absorption test | IS 10810-28 |
| (e) | | **Flammability Test** | |
| (i) | | Flammability test for single cable | As per IEC-60332 Part-1 |
| (ii) | | Flammability test for bunched cables | As per IEC-60332 Part-3 CAT-B |
| (iii) | | Flammability test for complete cable | As per IEEE-60383 |
| (iv) | | Swedish Chimney test | As per SEN-SS-424-1475-F3 |
| (f) | | ***Fire survival test*** | As per IEC- 60331-11 for min 3 Hrs at 950ºC |
| | | | |
| 12.0 | | **Allowable Tolerance** | +2 mm (max.) |
| 13.0 | | **CABLE DRUMS** | |
| (a) | | Type of Drum | Wooden Drum as per IS 10418 / Steel Drum As per Annexure I |
| (b) | | Standard drum length | 500m (+) 5% (as specified in BOQ Cum Price |
| (c) | | Painting | Entire surface to be painted |
| (d) | | Outermost Layer | To be covered with water proof polyethylene |
| (e) | | Particular information on Drum | Both the end of cables shall be properly sealed with heat shrinkable PVC / rubber caps secured by 'U' nails so as to eliminate ingress of water during transportation, storage & erection.<br>Wood preservative anti-termite treatment shall be applied to the entire drum |

**NOTE: Suitable fire-retardant material fillers shall be used for filling in the interstices. Two layers of plain glass binder tape should be applied over the laid-up cores.**

## 7. Cable Trays

Cable Tray and Cable Ladder systems are intended for the support and accommodation of cables and possibly other Electrical equipment in Electrical/Instrumentation/Communication systems.

### a. DESIGN AND FABRICATION OF CABLE TRAYS / LADDERS:

i.The cable trays / ladders shall be fabricated according to the design specified by IEC 61537 and should be tested for Safe Working Load (SWL). The relevant details of SWL and the load chart with respect to SWL, supporting distance and the deflection should be according to the following chart.

| Safe Working Load (SWL) with a span length up to 3 meters | | | |
|---|---|---|---|
| Description | Side | Width | Span length (in meters) |

| | Height (in mm) | (in mm) | 1.5m | 2m | 2.5m | 3m |
|---|---|---|---|---|---|---|
| | | | Permitted Load (in kg/meter) | | | |
| Perforated Cable Tray | 35 | 50 – 300 | 125 | 90 | 50 | - |
| | 60 | 50 – 600 | 150 | 100 | 50 | - |
| | 85 | 100 – 600 | 175 | 110 | 50 | - |
| | 110 | 100 – 550 | 185 | 130 | 75 | 60 |
| Cable Ladder | 45 | 200 – 600 | 180 | 140 | 100 | 55 |
| | 60 | 200 – 600 | - | 225 | 150 | 100 |
| | 110 | 200 – 600 | - | 310 | 200 | 140 |

Safe Working Load (SWL) with a span length up to 10 meters

| Description | Side Height (in mm) | Width (in mm) | Span length (in meters) | | | | | | |
|---|---|---|---|---|---|---|---|---|---|
| | | | 4m | 5m | 6m | 7m | 8m | 9m | 10m |
| | | | Permitted Load (in kg/meter) | | | | | | |
| Perforated Cable Tray for long span distance | 110 | 200 - 300 | 160 | 110 | 75 | - | 20 | - | - |
| | | 400 - 600 | 200 | 150 | 100 | - | 40 | - | - |
| | 160 | 200 - 300 | 230 | 180 | 140 | 100 | 70 | - | - |
| | | 400 - 600 | 250 | 200 | 160 | 130 | 100 | - | - |
| Cable Ladder for long span distance | 110 | 200 - 300 | 160 | 110 | 80 | 40 | - | - | - |
| | | 400 - 600 | 210 | 150 | 100 | 70 | - | - | - |
| | 160 | 200 - 300 | 230 | 180 | 140 | 100 | 70 | - | - |
| | | 400 - 600 | 250 | 200 | 160 | 130 | 100 | - | - |
| | 200 | 200 - 600 | - | - | 300 | 250 | 200 | 140 | 100 |

ii. Fabrication of Tray / Ladder and accessories at site and welding is not permitted. In unavoidable circumstances, If any cut or holes are made in the trays/Ladder/ accessories, zinc spray need to be applied over the surface. The metal edge has to be protected by edge protection sleeves to avoid cable damage. Edge of the supports has to be protected with plastic END caps. Screwed connections and internal fixing Devices should not create any damage to the cable when correctly fixed. Sudden or jerky motions shall not be used to tighten reusable screw connections.

iii. Cables shall run in cable tray/ladder mounted horizontally or vertically on cable tray support system which in turn shall be supported from floor, ceiling, overhead structures, trestles, pipe racks, trenches or other building structures using mounting accessories.

iv. The cable tray and all accessories shall be fabricated from sheet steel and has to be hot dip galvanized against corrosion confirming to ISO 1461-1999 for installations in both indoor and outdoor applications & should have a Base Perforation Class B according to IEC 61537. The cable trays shall be supplied in standard lengths of 3000mm and the width of the tray shall be as follows.

Width: 50, 100, 150, 200, 300, 400, 500, 600 & 750 mm.

v. All the cable tray accessories like Bend's, TEES's, Cross over's etc should be designed in accordance with IEC 61537 and shall be factory fabricated. The accessories shall be from the same material as of the tray and modular type, it should be connected with the trays by using fasteners. Typical details of trays, fittings and accessories etc are shown in the enclosed drawings.

vi. For Cable trays designed, tested and confirming to IEC 61537, thickness of cable tray should be according to the manufacturer's catalogue. For locally fabricated and non-tested tray, thickness should be 2 mm up to span length of 1.5-meter, 2.5 mm for span length between 2 to 3 meter and 3 to 4 mm for span length between 4 and 10 meters.

vii. Cable Ladder:

- The cable Ladder and all accessories shall be fabricated from sheet steel and has to be hot dip galvanized against corrosion confirming to ISO 1461-1999 for installations in both indoor and outdoor applications & should have a Free Base Area classification Y according to IEC61537. The cable ladders shall be supplied in standard lengths of 3000/6000 mm and the width of the tray shall be as follows.

Width: 200 to 1200 mm in multiples of 100 mm

- Maximum rung spacing in the ladder shall be 300mm. The rung's should be made of C profiles suitable to fix cables by special metal clamps according to the drawing. The ladder shall be of riveted and foldable type for easy transportation and to avoid damage during transportation and storage. All the ladder accessories like Bend's, TEES's, Cross over's etc should be designed in accordance with IEC 61537 and shall be factory fabricated. The accessories shall be made from the same material as of the ladder and modular type; it should be connected with the ladder by using fasteners. The details of ladders, fittings and accessories .etc are shown in the enclosed drawing.

- For Cable Ladders designed, tested and confirming to IEC 61537, thickness of cable Ladder should be according to the manufacturer's catalogue. For locally fabricated and non-tested Ladder, thickness should be 2.5 mm up to span length of 1.5 to 2 meter, 3 mm for span length between 2.5 to 4 meter and 3 to 4 mm for span length between 5 and 10 meter

**b. SPECIFICATION FOR HOT DIP GALVANIZING PROCESS**

(For Mild Steel Used for Earthing, Cable Trays or Junction Boxes for Electrical Installation.)

**i. Quality of Zinc**

Zinc to be used shall conform to minimum Zn 98 grade as per requirement of IS:209-1992.

**ii. Coating Requirement**

Minimum weight of zinc coating for mild steel flats with thickness upto 6 mm in accordance with IS:6745-1972 shall be 400 g/sqm.

The weight of coating expressed in grams per square metre shall be calculated by dividing the total weight of Zinc by total area (both sides) of the coated surface.

The Zinc coating shall be uniform, smooth and free from imperfections as flux, ash and dross inclusions, bare patches black spots, pimples, lumpiness, runs, rust stains bulky white deposits, blisters.

Mild steel flats / wires shall undergo a process of degreasing pickling in acid, cold rinsing and then galvanizing.

**c. COVER FOR CABLE TRAYS / LADDERS**

Cover for trays/ladders to protect the cable insulation from falling objects, water droplets, harmful effects of ultraviolet rays and accumulation of dust. The cover shall be made either from Hot Dip Galvanized sheet steel or superior quality Double Dip Galvanized Sheets. For Outdoor application, Double dip Galvanized material shall be used. The covers should be fitted properly to the Ladder / Tray by using pre fixed and tested locks which ensure that covers are fitted rigidly to Tray / Ladder. For outdoor application in high wind areas, additional cross over beadings to be used for fixing the cover on tray / ladder of width more than 500 mm.

**d. MOUNTING ACCESSORIES (SUPPORTS AND BRACKETS):**

The mounting accessories shall be fabricated from steel and has to be hot dip galvanized against corrosion confirming to ISO 1461-1999 for installations in both indoor and outdoor applications and should be of completely modular type.

All supports and Brackets should be factory made, hot dip galvanized after completing welding, cutting, drilling, other

machining operations and tested according to IEC 61537 according to the arrangements in the enclosed drawing. The system shall be designed such that it allows easy assembly at site by using Bolts and Nuts. The main support and brackets shall be fixed at site using necessary brackets, clamps, fittings, bolts, nuts and other hard ware etc to form various arrangements required to support the cable trays. Welding of the components at the site shall not be allowed.

**Joints**

Joints shall be smooth and without projections or rough edges that may damage the cables.

The Concessionaire will be required to cover joints with rubber cement or other non hardening rubberised or plastic compounds if in the opinion of the Department joints may damage cables.

Joints shall as far as possible be arranged to fall on supports. The two cable tray ends shall butt tightly at the centre of the splice and the splice shall be bolted to each cable tray be means of at least 8 round head bolts, nuts and washers. Splices shall have the same finish as the rest of the tray.

**e. FIXING TO SUPPORTS**

Trays shall be bolted to supports by at least two round head bolts per support. Bolts shall be securely tightened against the tray surface to avoid projections which might damage cables DURING INSTALLATION.

**f. FIXING TO THE STRUCTURE**

Where installed on concrete or brick, the supports for cable trays and ladders shall be securely fixed by means of at least 2 heavy duty, expansion type anchor bolts. Cantilevered trays shall be supported by a minimum of two expansion bolts per support.

It is the responsibility of the Concessionaire to ensure that adequate fixing is provided since cable trays and ladders that work loose shall be rectified at his expense. The fixing shall take in to account site conditions that prevail during installation.

Horizontal trays and ladders shall in general be installed below slabs, ceilings, etc. to

facilitate access during installation of cables.

Multiple runs shall be spaced at least 300 mm apart unless a different spacing is specified.

Corrosion Protection:

The cable tray / ladder/accessories shall be of HOT DIP Galvanized (ISO 1461-1999) for installations in corrosive atmospheres both indoor and outdoor application. Sample tray / ladder / accessories / mounting accessories and supports should be salt spray tested according to ISO 9227 for > 500 hours. (*550 hours according to class 6 for Hot dip Galvanized surface as per ISO)

**g. TESTING AND CERTIFICATION IF INSTALLATION :**

Cable tray / Ladder, bend, T Bend, cross, and all supports are to be tested for Safe Working Load (SWL), deflections, Impact resistance, Salt Spray & Electrical continuity test according to IEC 61537. The cable tray/ladder should not deflect more than 1/100th of the span length at SWL in Mid span and the transverse deflection of all mounting accessories at SWL shall not exceed 1/20th of the length. The cable tray / cable ladder should be tested up to 1.7 times SWL at minimum and maximum room temperature. The temperature classification of cable tray system should be - 5 to + 150°C.

**h. MARKING, DOCUMENTATION, COMPLIANCE AND INSPECTION:**

Each system component shall be durably and legibly marked with:

- the manufacturers or responsible vendor’s name or trade mark or identification mark;
- a product identification mark which may be, for example, a catalogue number, a symbol, or the like.

When system components other than cable tray lengths and cable ladder lengths are supplied in a package, the product identification mark may be, as an alternative, marked on the smallest package unit.

Marking shall be applied, by moulding, pressing, engraving, printing, adhesive labels, or water slide transfers. Compliance is checked by inspection and, for marking on the product, by rubbing by hand for 15 s with a piece of cotton cloth soaked with water and again for 15 s with a piece of cotton cloth soaked with petroleum spirit. Marking made by moulding pressing, or engraving is not subjected to the rubbing test. After the test, the marking shall be legible.

If a system component is stored and transported at a temperature outside the declared minimum and maximum temperatures, the manufacturer or responsible vendor shall declare the precautions and the alternative temperature limits. Compliance is checked by inspection.

The manufacturer or responsible vendor shall provide in his literature all information necessary for the proper and safe installation and use of the cable tray system and cable ladder system. The SWL and impact resistance is valid for the whole temperature classification declared. The information shall include

**i. FIRE RETARDANT CABLE PAINT & FIRE BARRIER**

The fire retardant paint / barrier shall be listed by independent test agencies such as UL, FM or OPL and be tested to, and pass the criteria of ASTM E 814 ( UL1479) standard test method for fire test through- penetration fire stops and ASTM E 1996 (UL 2079) standard test method for fire resistive joint system/

**j. FIRE RETARDANT CABLE PAINT**

The Fire-resistant cable coating / painting shall be intumescent / ablative, water based compound, The coating shall expand up to 10 times, supplied in a manufacturer seal container indicating manufacturing and expiry dates. The coating material shall be non-toxic, asbestos free, & halogen free and shall have good mechanical strength. The colour of paint shall be white and density of coating shall be 1.3kg/ltr, coating shall have a snap time of 30 minutes, the expansion shall begin at 230 deg.C and it shall have a oxygen index of 41%.

Coating shall be applied by ordinary paint brush after cleaning the cables of dust and oil deposition. A minimum textured finish of 3 mm wet film thickness shall be achieved by applying the material in 2-3 layers leaving intervals of 2 to 8 hours depending upon the moisture and thickness, moisture and temperature hours between each coat.

**k. FIRE BARRIER SHEET FOR FLOOR AND WALL SEALING**

The framing & fixing part of fire barrier sheet shall be very simple & directly fixed around walls & floors by help of anchored bolts & washer. For 2-hour fire rating the fire barrier sheet shall be minimum 7.62 mm thick and shall be cut as per the profile of penetration and opening. The small gap left around the penetration shall be closed with fire rated soft & mouldable putty. Fire barrier must be design on the intumescent technology to seal larger penetration through the fire rated walls & floors. Fire barrier must be a composite construction with the quality incorporated with organic/ inorganic fire resistive elastomeric sheet with specific **gravity** of 1.6 gm/ cubic centimeter.

### 7.2.6 LT Panel

**1. General Requirements**

This specification covers requirements for Supply, Erection, Testing and Commissioning of LT Panels. The equipment offered by the Concessionaire shall be complete in all respects. Any material and component not specifically stated in this specification but which is necessary for trouble free operation of the equipment and accessories specifically excluded. All such equipment / accessories shall be supplied without any extra cost. Also, all similar components shall be interchangeable and shall be of the same family type and rating for easy maintenance and low spare inventory.

The general power supply of the 433 / 250 Volt-level to the different equipment will occur from the Electrical room in the Control Centre on both ends of the tunnel to the Niches and then further to the ultimate consumers through field distribution boards.

At the Control Building one low voltage main distribution cabinet is situated for Grid and one for the UPS from where the Grid and UPS power is supplied to the Niches and then further to the ultimate consumers.

All power and control units shall be installed into distribution cabinets, all different voltages (e.g. main power, UPS power, different control units and so on) shall be placed in separated cabinets.

**2. Code and Standards**

Compliance with all applicable Indian standards, Indian Electricity Act and Indian Electricity rules.

| | | |
|---|---|---|
| IS 5039 | : | Distribution Feeder Pillars |
| IS 375 / 1963 | : | Making and arrangement for switchgear, bus-bars, main connections & auxiliary wiring |
| IS 694 | : | PVC insulated cables for working voltages up to and including 1100V. |

| | | |
|---|---|---|
| IS 13779 | : | A.C. Static Electricity Meters. |
| IS 1248 | : | Electrical Indicating instruments. |
| IS 1567 / 1960 | : | Metal clad switches (Current rating not exceeding 100A) |
| IS 1951 / 1916 | : | Polyvinyl chloxide sleeving for electric purposes. |
| IS 2147 / IS 12063 | : | Degree of protection provided by enclosures for low voltage switchgear and control gear. |
| IS 5 | : | Colors for ready-mixed paints and enamels. |
| IEC 60947/ IS 13947 (Part-2) | : | A.C. Circuit breakers. |
| IS 8828 | : | Miniature Circuit breakers. |
| IS 12640 | : | Residual Current Operated Circuit breakers. |
| IS 2448 / 1962 | : | Adhesive insulating tapes. |
| IS 2551 | : | Danger Notice Plates. |
| IS 2705 | : | Current Transformers. |
| IEC 60947/ IS 13947 | : | Contactors and motors starter for voltages not exceeding 1000 V AC or 1200 V DC. |
| (Part-4, Sec-1) | : | |
| IS 13947 (Part-5, Sec-1) | : | Control Circuit Devices and Switching Elements |
| IS 13947 (Part-1&5) | : | Actuators, Indicators |
| IS 13947 (Part-1&5) | : | Timers |
| IS 3043 | : | Code of practice for earthing. |
| IS 3072 | : | Installation and Maintenance of switchgear. |
| IS 3202 | : | Code of practice for climate proofing of electrical equipment. |
| IS 3231/ IS 8686 | : | Electrical relays for power system protection. |
| IS 4237 | : | General requirements for switchgear and control gear for voltages not exceeding 1000 V. |
| IS 5082 | : | Wrought Aluminum & Al alloy for electrical purposes. |
| IS 6875 | : | Switches and push-buttons. |
| IS 8623 | : | Specification for factory-built assemblies of switchgear & control gear for voltages up to & including 1000 V AC. |
| IS 10118 | : | Code of practice for selection, installation and maintenance of switchgear and control gear. |

| | | |
|---|---|---|
| IS 11353 | : | Guide for uniform system of marking and identification of conductors and apparatus terminals. |
| IS 12021 | : | Specification of control transformers. |

Equipment in line with any other authoritative / internationally recognized standards such as IEC, British, USA and German etc. shall also be considered if it ensures performance equivalent or superior to Indian Standards. Prior approval shall be obtained from consultant for use of this equipment / material. In such cases the decision of consultant shall be final and binding.

**3. Quality Assurance**

Manufacturers regularly engaged in manufacture of panel boards and enclosures, of types, sizes and ratings required, whose products have been in satisfactory use in similar service for not less than 5 years

**4. Guarantee**

Manufacturer shall provide guarantee for work under this section. However, such guarantee shall be in addition to and not in lieu of all other liabilities which manufacturer and Concessionaire may have by other provisions of the contract document.

The Panel Boards shall be guaranteed against trouble free operation, defective workmanship, materials and design for a period of 18 months from the date of supply or 12 months from the date of erection and commissioning, whichever is earlier. Any defects during this period shall be rectified free of cost.

**5. Submittals**

Concessionaire to submit general arrangement diagrams with front, side, top and bottom view and inside view.

General arrangement diagrams shall include outline and dimensions, voltage, main bus capacity, circuit breaker details and their arrangement / sizes.

All drawings shall also indicate location / description of all operating / indicating components mounted on the front / rear of the panel for all feeders / starters.

Typical control schematic diagram for each type giving designation to be refereed on Single Line Diagram/BOQ.

Terminal block details for all feeders / starters power and control terminals provided for external as well as internal wiring connections.

Panel board foundations with necessary dimensions.

Details of shipping sections along with all dimensions.

Bill of material giving make / rating / catalogue number of all components of the complete switch board.

Shop drawings to scale of the room layout indicating the panel location

**6. Delivery**

All panels shall be carefully packed to avoid damage during transit. Panel boards shall be wrapped in polyethylene sheets for local shipment, whereas for outstation delivery in addition to polyethylene sheet the panels shall be packed in wooden crates to prevent damage to the finish.

**7. Panel Board Enclosures and Accessories**

**Constructional Details of Panel Boards**

All Panel Boards shall be metal enclosed, indoor, floor / wall mounted, free-standing type.

All Switchboards frames and load bearing members shall be fabricated using suitable mild steel structural sections or pressed and shaped cold rolled sheet steel of thickness not less than 2.0mm. Frames shall be enclosed in cold rolled sheet steel of thickness not less than 2.0mm. Doors and covers shall also be of cold rolled sheet steel of thickness not less than 1.6mm. Stiffeners shall be provided wherever necessary. Rear doors shall min 2.00 mm thick CRCA and provided with three pin handle and lock.

All panel edges and cover / door edges shall be reinforced against distortion by rolling, bending or by the addition of welded reinforcement members. The top covers of the panels should be designed such that they do not permanently

bulge / bend by the weight of maintenance personnel working on it.

The complete structures shall be rigid, self-supporting, and free from flaws, twists and bends. All cutouts shall be true in shape and devoid of sharp edges.

All LT Panels shall be of dust-proof and vermin-proof construction and shall be provided with a degree of protection of IP: 54 as per IS: 2147.

All Feeder Pillars and Secondary Panels shall be of dust-proof, vermin-proof and weather-proof construction and shall be provided with a degree of protection of IP : 55 as per IS : 2147.

All cutouts shall be provided with synthetic rubber gaskets. The gaskets, wherever specified, shall be of good quality synthetic rubber with good aging, compression and oil resistance characteristics suitable for panel applications. Preference shall be given to Heat resistant – EPDM Gaskets.

Panels shall be supplied with base frames made of structural steel sections, along with all necessary provision for fixing to foundation / floor as required. The base frame height shall be such that floor finishing to be done by Owner after erection of the switchboards does not obstruct the movement of doors and cover etc.

All Panel Boards shall be divided into vertical section, comprising of various compartments as mentioned below. However, these compartments may be combined in case of Feeder Pillars and Secondary Panels.

Feeder Pillars and Secondary Panels shall have canopy on the top. Canopy shall have slope so as not to let the rainwater accumulate on the same. The canopy shall extend beyond the panel body to avoid any rainwater falling inside the panel.

**Bus-bar Compartment**

A completely enclosed bus-bar compartment shall be provided for the horizontal and vertical bus-bars. Bolted covers shall be provided for access to horizontal and vertical bus-bars and all joints for repair and maintenance, which shall be feasible without disturbing any feeder compartment. All bus-bars shall be in separate compartment. Covers shall be provided with name plates indicating “Danger - Bus Bars” on it. Colour of the plate shall be White with letters in Red of danger name plates shall be inscribed with 6 mm size lettering.

Shrouding for Bus Bar with above 1250 A current rating shall be provided. These shrouds located near conductors shall be made using non-magnetic materials.

**Switchgear / Feeder Compartment**

All equipment associated with an incomer or outgoing feeder shall be housed in a separate compartment of the vertical section. The compartment shall be sheet steel enclosed on all sides. The front of the compartment shall be provided with the hinged single leaf door with “Master Key” lock. The feeders compartment door shall have two number anodized inscription plates. One inscription plate shall bear the feeder number and feeder rating and fixed to the door with rivets. The other inscription plate shall bear the feeder name and shall be fixed by screws. The feeder name plates shall be interchangeable.

**Cable Compartment or Cable Alley**

A full-height vertical cable alley of minimum 300mm width shall be provided for power and control cables. Cable alley shall have no exposed live parts and shall have no communication with Bus-bar compartment. Cable terminations located in cable alley shall be suitably shrouded to prevent accidental contact by falling of tools etc. It shall be of such construction as to allow cable cores with lugs to be easily inserted in the feeder compartment for termination. The Concessionaire shall furnish suitable plugs to cover the cable openings in the partition between feeder compartment and cable alley. Cable alley door shall be hinged. Cable alley door shall be provided with name plates indicating “Cable Alley” on it.

**Control Compartment**

A separate compartment shall be provided for relays and other control devices associated with a circuit breaker.

Sheet steel barriers shall be provided between two adjacent vertical panels running to the full height of the switchboards, except for the horizontal Bus-bar compartment. Synthetic rubber gasket shall be provided between the panel sections to avoid ingress of dust into panels. Each shipping section shall have full metal sheets at both ends for transport and storage.

After isolation of power and control circuit connections it shall be possible to safely carryout maintenance in a compartment with the Busbar and adjacent circuit live. Necessary shrouding arrangement shall be provided for this purpose. Wherever two breaker compartments are provided in the same vertical section, insulating barriers and

shrouds shall be provided in the rear cable compartment to avoid accidental touch with the live parts of one circuit when working on the other circuit.

All 415 V switchgear (circuit-breaker) panels shall be of single-front type. All Panels shall also be of single-front construction. All single-front switchboards shall be provided with single-leaf, hinged or bolted covers at the rear. The bolts shall be of captive type. The covers shall be provided with 'Danger' labels. All panel doors shall open by 90deg. or more. The panel door shall be openable only after switching of the incoming power supply.

Complete shrouding / segregation shall be provided between incoming and outgoing bus links of breakers. In case of bus coupler breaker panels, the bus-bar connection to and from the breaker terminals shall be segregated such that each connection can be approached and maintained independently with the other bus section live.

All equipment and components shall be neatly arranged and shall be easily accessible for operation and maintenance. The internal layout of all modules shall be subject to consultants approval and shall be provided with bakelite shrouding.

The tentative power and control cable entries (top/bottom) required are indicated in the "Bill of Quantity". However, the Owner / Consultant reserve the right to alter the cable entries, if required during detailed engineering, without any additional commercial implication.

Each switchboard shall be provided with un-drilled, removable type gland plate, which shall cover the entire cable alley. Concessionaire shall ensure that sufficient cable glanding space is available for all the cables coming in a particular section through gland plate. For all single core cables, gland plate shall be of non-magnetic material. The gland plate shall be provided with gasket to ensure enclosure protection.

**Gland Plates**

Gland plates for 2 Core, 3 Core, 3½ Core, 4 Core Cables shall be 2.5 mm thick CRCA zinc passivated. Thickness of zinc passivation shall be 100 microns. Wherever, the size of gland plates exceeds 600 mm same shall be split into two parts and provided with adequate supporting arrangement. Earth continuity between cable armour and panel body shall be maintained. Single core shall have aluminum gland plates of min 6mm thick.

**Clearances**

The minimum clearance in air between phases and earth for the entire run of horizontal and vertical busbars and bus-link connections at circuit-breaker shall be 25mm. For all other components, the clearance between "two live parts" shall also be twenty-five (25) mm throughout. For a live part and an earthed part the clearance shall be twenty (20) mm minimum. Wherever it is not possible to maintain these clearances, insulation shall be provided by sleeving or barriers. However, for horizontal and vertical bus-bars the clearances specified above should be maintained even when the bus-bars are sleeved or insulated. All connections from the bus-bars up to MCCB / SFU / FSU shall be fully shrouded / insulated and securely bolted to minimize the risk of phase to phase and phase to earth short circuits.

**Power Bus-bars and Insulators**

All 415 V Panel Boards, shall be provided with three phase and neutral bus-bars. Entire Bus-bar system shall be insulated with colour coded, heat shrinkable PVC sleeves.

All bus-bars and jumper connections shall be of high conductivity aluminum alloy / copper of adequate size.

The cross-section of the bus-bars shall be uniform throughout the length of switchboard and shall be adequately supported and braced to withstand the stress due to the specified short circuit currents. Neutral Bus-bar short circuit strength / cross section shall be same as main bus-bars up to 400 Amps.

All bus-bars shall be adequately supported by non-hygroscopic, non-combustible, track-resistant and high strength sheet moulded compound or equivalent type polyester fiber glass moulded insulators. Separate supports shall be provided, for each phase and neutral Bus-bar. If a common support is provided, anti-tracking barriers shall be provided between the supports. Insulator and barriers of inflammable material such as Bakelite / Hylam, shall not be accepted. The Bus-bar insulators shall be supported on the main structure.

All copper to aluminum joints shall be provided with suitable bi-metallic washers. Alternatively direct Bus Bar joints can be made between copper and aluminium Bus Bar if tinned copper Bus Bars are used.

All bus-bars shall be colour coded as per IS: 375.

All bus-bars shall have PVC sleeves (not tapes) wherever called for in the specification.

**Earth Bus and Earthing**

A galvanized steel / aluminum earth bus of suitable size shall be provided at the bottom of each panel and shall extend throughout the length of each Panel. It shall be welded / bolted to the framework of each panel and breaker earthing contact bar.

The earth bus shall have sufficient cross section (250 sq. mm. minimum) to carry the momentary short circuit and short time fault current to earth, without exceeding the allowable temperature rise.

Suitable arrangements shall be provided at each end of the horizontal earth bus for bolting earthing conductors. The horizontal earth bus shall project out of the Panel ends and shall have predrilled holes for this connection. All joint splices to earth bus shall be made through at-least two bolts, and taps by proper lug and bolt connection.

All non-current carrying metal work of the Panel shall be effectively bonded to the earth bus. Electrical conductivity of the whole switchgear enclosure framework and truck shall be maintained even after painting.

All metallic cases of instruments and other panel-mounted equipment shall be connected to earth by independent stranded copper wires of size not less than 2.5 sq. mm. All the equipment mounted on the door shall be earthed through flexible wire / braids. Insulation colour code of earthing wires shall be green.

CT secondary neutral point earthing shall be at one place only, i.e. on the terminal block. Such earthing shall be made through links so that earthing of one secondary circuit can be removed without disturbing the earthing of other circuit.

All hinged doors having potential carrying equipment mounted on it shall be earthed by flexible wire / braid. For doors not having potential carrying equipment mounted on it, earth continuity through scraping hinges / hinge pins of proven design may also acceptable. The Concessionaire shall establish earth continuity at site also.

**Switchgear:**

**i.LT Air Circuit Breakers (ACB's)**

**Technical Parameters**

The ACB shall conform to the requirements of IEC 60947-2 / IS 60947-2 and shall be type tested & certified for compliance to standards from–CPRI, ERDA / any accredited international lab. The circuit breaker shall be suitable for 415 V + 10%, 50Hz supply system. Manufacturer should submit Combined sequence test certificate from CPRI/ERDA

The circuit breakers shall be for continuous rating at -15 to 30 deg C ambient temperature. The Rated insulation voltage shall be 1000 volts AC & Rated impulse withstand Voltage shall be 12kV for main circuit.

Rated service short Circuit Breaking capacity shall be 50KA and should be equal to the Rated ultimate Short circuit breaking capacity (Icu) and short circuit withstand values (Icw) for 1 sec.

**Constructional Features**

The ACB shall be 3/ 4 pole with modular construction, horizontal draw out type, manually or electrically operated version as specified in BOQ and fully interlocked.

Main current carrying contacts of ACB shall be silver plated and suitable arcing contacts with proper arc chutes shall be provided to protect the main contacts. Arc chutes shall be provided for each pole, and these shall be suitable for being lifted out for the inspection of the main and the arcing contacts without using any tools.

The ACB shall be provided with a door interlock i.e. door should not be open when circuit breaker is closed and breaker should not be closed when door is open.

All 4 Pole ACBs should have 100% neutral rating.

**Cradle**

The Circuit Breaker cradle shall be designed and constructed to permit smooth withdrawal and insertion. The movement shall be free of jerks, easy to operate and positive.

The draw out Circuit Breaker shall have the following 3 distinct and separate positions wrt cradle.

"Service" -- Both main and secondary isolating contacts closed

"Test" -- Main isolating contacts open and secondary isolating contacts closed

"Isolated" -- Both main and secondary isolating contacts open

**Circuit Breaker Interlocking**

It shall not be possible for the Breaker to be rack out / withdrawn from the cubicle when in the "ON" position.

It shall not be possible for the Breaker to be switched "ON" until it is either in the fully inserted position or, for testing purposes, it is in the fully isolated position.

It shall not be possible for the Circuit Breaker to be plugged in unless it is in the OFF position.

**Circuit Breaker Auxiliary Contacts & accessories**

The Circuit Breaker shall have minimum 4 NO/NC auxiliary contacts rated at 16 amps 415 volts 50 Hz. These contacts shall be approachable from the front. They shall close before the main contacts when the Circuit Breaker is plugged in and vice versa when the Circuit Breaker is Drawn Out of the cubicle.

All accessories of ACBs like shunt trip coil, under voltage trip coil, closing coil etc. shall be click fit type and front mounted. It should be possible to know the control voltage ratings for all electrical accessories without opening the panel door.

**External Neutral CT** should be provided for all 3 pole ACBs for Earth Fault sensing & to avoid nuisance tripping due to unbalance loads.

Mechanical operation counter to be provided for all ACBs

**Protective Devices**

All ACBs (except bus couplers) shall be provided with micro-controller based release to offer accurate and versatile protections with complete flexibility and in the following zones:

- Overload (Phase & Neutral) protection with adjustable time delay.
- Short time protection with intentional delay.
- Instantaneous protection.
- Ground fault protection with intentional time delay.

The release should provide local LED indication for identification of type of fault, without requiring using external power supply.

The release shall draw its power from the main breaker CTs and shall require no external power supply for its operation, There shall be provision for aux. supply for display of parameters during off or lightly loaded conditions.

The release should display actual % loading at any instant.

Release shall be password protected to prevent unauthorized access to protection settings

Releases shall have 2 storable sets of LSIG protection settings to provide adequate protection against loads varying as per time & source changeover from Transformer to DG.

The release shall meet the EMI / EMC requirements.

**Metering & Communication:** Release should have LED/LCD display for of Phase & Neutral currents and last 20 fault / trip history.

**Transformer & DG set** Incomer ACB releases shall have LED/LCD display showing all Power & Energy Parameters (I, Imax, %loading, Iavg, V, Freq, PF, W, VAr, VA, Wh, VArh, Vah, MD-Active, MD-Reactive, MD-Apparent, Temperature in each Phase)

The release shall also give additional protection against Current & Voltage Unbalance, Under Voltage, Over Voltage, Under frequency, Over frequency, Lead/Lag PF, Maximum Demand, Phase Sequence etc

All Main Incomer ACBs shall have inbuilt Temperature rise protection for protection against abnormal Temperature rise at terminals.

The Release shall be provided with RS485 communication port on MODBUS RTU protocol

**Safety Features**

- Draw out ACBs shall be provided with automatically operated safety shutters to prevent accidental contact with live contacts when breaker is withdrawn from the Cradle.
- IFor safety of users, interlock should be provided between breaker operating mechanism & the arc chutes to prevent closing in case the arc chutes are not properly secured.

- The insulation material used shall conform to Glow wire test as per IEC60695-2-1
- The racking shutter should open only when ACB is OFF to avoid unauthorized racking operation.
- Mechanical and electrical anti pumping devices shall be incorporated in the electrically operated ACB's as required.

**ii.Moulded Case Circuit Breakers (MCCB's)**

The Moulded case circuit Breaker (MCCB) shall confirm to the latest IS 13947 (Part-2) and IEC 60947-2. The MCCB shall comply with the isolation function requirement of IEC 60947-2 Section 7.12 & marked as suitable for isolation and disconnection to facilitate safety of operating personnel while the breaker is in use.

The MCCB shall have a rated service short circuit breaking capacity (Ics) not less than 25/40/50/65 KA rms at 415V, 50 Hz AC, 400 A & 250 A as specified in SLD.

The Service breaking capacity (Ics) shall be equal to ultimate breaking capacity (Icu) unless otherwise specified.

MCCB's shall be suitable for rated operation voltage upto 690 V AC, 50 Hz & rated insulation voltage upto 750 V AC, 50 Hz.

MCCBs shall be of triple pole / four pole construction. Operating mechanism shall be quick-make, quick-break and trip-free type. The "ON" , "OFF" and "TRIP" positions of the MCCB's shall be clearly indicated and visible to the operator when mounted as in service. Front of door operating handle shall be provided with pad lock and door interlock. Front of door operating handle shall be provided with door interlock defeat mechanism to facilitate inspection of the MCCB during 'ON' position.

The MCCB shall be current limiting type. MCCB shall have Arc extinguishing device contained in a compact, high strength, heat resistance, flame retardant, halogen free insulating moulded case with high withstand capability against thermal and mechanical stresses.

The trip command of releases in MCCB shall over ride all the other commands. The MCCB shall employ maintenance free double break contact system to minimise the let through energies and capable of achieving Discrimination up to the full short circuit capacity of the downstream MCCB. The MCCB shall not be restricted to line / load connections. MCCB shall be provided with test trip Push Button to check the proper function of tripping mechanism.

MCCBs shall be capable of withstanding the thermal stresses caused by overloads and locked rotor currents of values associated with protective relay settings of the motor starting equipment and the mechanical stress caused by the peak short-circuit current of value associated with the switchgear rating. The maximum tripping time under short circuit shall not exceed 8 milliseconds.

Where mechanical interlocking is called-for between two Incomer and Bus Coupler or between two Incomers without Bus Couplers, proper arrangement for built-in Ronis/ Coded key interlocking shall be provided.

MCCB terminals shall be shrouded and designed to receive Bus Bar Links /cable lugs for cable sizes relevant to circuit ratings.

**Protection**

MCCBs shall be provided with Thermo-Magnetic / microprocessor type releases 400 & 250 A, TPN.

The MCCB's above 250 Amps shall be provided with fully interchangeable thermo-magnetic / microprocessor based overload and short circuit release. Load indication LED shall be integral part of electronic releases. All electronic releases shall be EMI / EMC compatible.

Microprocessor Releases shall have Thermal Memory i.e. when the breaker shall re-close after tripping on overload, then the thermal stress caused by the overload if not dissipated completely, shall get stored in the memory of releases and this thermal memory shall ensure reduced tripping time in case of subsequent overloads and earth fault. Realistic Hot/Cold curves shall take into account the integrated heating effects to offer closer protection to the system.

Where Earth fault protection are indicated they shall be integral with MCCB's and have adjustability from 20% to 100% of rated current with adjustable time delays to aid discrimination on earth faults. The integrated system shall be immunized against nuisance tripping as per IEC 61000-4 standards.

In case of 4 Pole MCCB the neutral shall be defined and capable of offering protection upto full rating (0/50/100% value of phase current). In case of critical supply feeder, neutral protection shall be 0/80/160% of phase current.

**Accessories**

The MCCB shall have common field fittable snap-on auxiliaries for entire range & above 160 Amps the accessories like tin plated spreaders and phase Barriers should be integral part of MCCB's.

**Indicating Instruments (Digital Type)**

All indicating and integrating meters shall be flush mounted on panel front. The instruments shall be of at least 96mm. Square size Digital Type with Built-in Selection, and shall have an accuracy class of 1.0 or better. The covers and cases of instruments and meters shall provide a dust and vermin proof construction. Digital meters to be provided for single phase Panels shall not incorporate Built in Selector Switch.

All instruments shall be compensated for temperature errors and factory calibrated.

**Instrument Transformers**

All current transformers shall be tape insulated type suitable for continuous operation at the temperature prevailing inside the switchgear enclosure, when the switchboard is operating at its rated condition and the specified ambient temperature. The class of insulation shall be 'E' or better.

All instrument transformers shall have clear indelible polarity markings. All secondary terminals shall be wired to separate terminals on an accessible terminal block where star point formation and earthing shall be done.

CT shorting links are to be provided to avoid burning / damage of CT's in case of opening of CT terminals.

Current transformers may be multi or single-core type. All CTs shall be provided with supports independent of Bus-bar/Bus-bar supports.

The CTs shall be located in such a way that they can be easily approached for maintenance without necessitating shut down of adjacent feeders.

**Selector Switches**

Selector switches shall be of rotary type, with plates clearly marked to show the function and positions. The switches shall be of sturdy construction suitable for mounting on panel front. Switches with shrouding of live parts and sealing of contacts against dust ingress shall be preferred.

Contacts of switches shall be spring assisted and shall be of suitable material to give a long trouble-free service.

**Push Buttons**

Push-buttons shall be of spring return, push-to-actuate type. Their contacts shall be rated to make, continuously carry and break 10 A at 240 V AC and 1 A (inductive) at 220 V DC.

All push-buttons shall have one normally open (1 NO.) and one normally closed (1 NC) contact, unless specified otherwise. The contact faces shall be of silver alloy.

All push-buttons shall be provided with integral plates marked with its function.

The colour of the button shall be as follows:

Green for motor Start / breaker Close.

Red for motor Stop / breaker OPENS.

All push-buttons on panels shall be located in such a way that Red push-buttons shall always be to the left of Green push-buttons.

All emergency push-buttons shall have mushroom knobs.

**Indicating Lamps**

Indicating lamps shall be of the panel mounting, LED type and low watt consumption. The LED lamps shall have plates marked with its function, wherever necessary.

Lamps shall have translucent lamp-covers of the following colours, as warranted by the application:

Red for R-Phase / MCCB "ON" / Contactor 'ON'

Yellow for Y-Phase

Blue for B-Phase

Green for Contactor 'OFF'

Amber for Breaker / Starter 'TRIP'

Lamp cover shall be easily replaceable from the front of the cubicle.

LED indicating lamps should be located just above the associated push-button / control switches. Red lamps shall invariable be located to the right of green lamps.

Internal Wiring, Control Terminal Blocks, Name Plate / Labels and Painting

**Internal Wiring**

All switchboards shall be supplied completely wired internally up to the terminals, ready to receive external cables.

All intercubicle and inter panel wiring and connections between panels of same switchboard including all bus wiring shall be provided by Concessionaire.

All auxiliary wiring shall be carried out with 1100 V grade, single core, stranded copper conductor, colour coded, PVC insulated wires. Conductor size shall be 1.5 mm2 (min.) for control circuit wiring & 2.5 mm2 (min.) for CT's.

PVC insulated; standard copper wires shall be used for wiring to devices mounted on moving parts such as hinged doors. The wire bunches from the panel inside to the door shall be properly sleeved or taped.

All wiring shall be properly supported, neatly arranged, readily accessible and securely connected to equipment terminals and blocks.

All internal wiring terminations shall be made with solder less crimping type tinned copper lugs which shall firmly grip the conductor or an equally secure method. Similar lugs shall also be provided at both ends of component-to-component wiring. Insulating sleeves shall be provided over the exposed parts of lugs to the extent possible.

Engraved core identification ferrules marked to correspond with panel wiring diagram shall be fitted at both ends of each wire. The ferrule shall be of self-locking type. The wire identification marking shall be in accordance with IS:375.

Wiring for equipment, which are to be supplied by the Owner and for which the Concessionaire has to provide mounting arrangement in his panels, shall also be provided by the Concessionaire, up to the terminal blocks.

All connections from vertical bus bars for individual modules above 100 A shall be by Copper / Aluminum links only. The cable connections for module up to 100 A shall be selected in such a way that there will not be any melting / shorting in case of a short circuit inside the module and the cable shall have current rating to carry the let through energy of the corresponding breakers in case of a fault. For power wiring colour coded wire insulation / tapes shall be provided.

**Control Terminal Blocks**

Control terminal blocks shall be of 1100 Volts grade, rated for minimum 10amps and in one piece molding. It shall be complete with insulating barriers, clip-on type terminals and identification strips. Marking on terminal strip shall correspond to the terminal numbering on wiring diagrams.

All terminal blocks shall be suitable for terminating on each side two (2) nos. stranded copper conductors of size up to 2.5 mm2 each.

All terminals shall be numbered for identification and grouped according to the function. Engraved white-in-black labels shall be provide on the terminal blocks.

Wherever duplication of a terminal block is necessary it shall be achieved by solid bonding links.

Terminal blocks shall be arranged with at least 100 mm clearance between two sets of terminal blocks. The minimum clearance between the first row of terminal blocks and the associated cable gland plate shall be 250 mm.

**Name Plates and Labels**

All Panel Boards shall be provided with prominent, engraved identification plates. The module identification plate shall clearly give the feeder number and feeder designation.

All name plates shall be of anodized aluminum with white engraved lettering on black background.

**Painting**

All sheet steel work shall be pretreated, in tanks, in accordance with IS: 6005. Degreasing shall be done by alkaline cleaning. Rust and scales shall be removed by pickling with acid. After pickling, the parts shall be washed in running water. Then these shall be rinsed in slightly alkaline hot water and dried. The phosphate surfaces shall be rinsed and passivated prior to application of stoved lead oxide primer coating. After primer application, two coats of finishing

synthetic enamel paint on panels shall be applied. Finishing paint on Panels shall be Powder Coated, Siemens Grey, shade RAL–7032 throughout Orange Peel Finish with Electrostatic method or as approved by the Owner's / Consultant while approving the shop drawings.

**LT Switchgear:**

Standard: IEC 60947 / IS 13947 amended to date.

Only approved makes of switchgears shall be used.

LT switchgears shall be provided with necessary in built over-current, and short circuit releases

**Energy meter:**

3-phase, 4-wire LT CT operated static energy meters (5A) (Class 0.5) with associated CT's (400/5 A, Class 0.5, 15 VA) shall be provided for each incomer to record energy consumption. Only owners approved makes of energy meter & CTs shall be used.

**MULTI-FUNCTION INSTRUMENT**

Multi-function instruments (for installation in the distribution cabinet's-door), shall be suitable to measure:

- current of all phases (L1, L2, L3)
- voltage of all phases (phase-neutral, phase-phase)
- active power
- apparent power
- reactive power
- power factor (cos φ)
- kWh
- kVarh

The multi-function instruments shall be equipped with an electric measuring element and a busable interface.

Further, the multi-function instruments shall be connectable to the current transformer (nA/5A), and they shall be equipped with a digital display and a keyboard for controlling. They also shall be equipped with a peak-value-memory.

**Ammeters:**

Moving iron spring-controlled type, flush mounted, 96 sq. mm. and 90-degree scale and clearly readable. Range 0-400A. Only Owner's approved makes shall be used.

**Voltmeters:**

Moving iron spring-controlled type, flush mounted, 96 sq. mm. and 90-degree scale and clearly readable. Range 0-500V. Only owner's approved makes shall be used.

The configuration of LT Panel shall be as per SLD and detailed design of the Concessionaire, subject to approved of the Independent Engineer.

**8. Distribution Cabinets - Jet Fans**

The jet fans shall be fed through reversible soft starter panels the soft starter shall be suitable to perform following tasks and specifications:

- adjustable launching ramp, stooping ramp, launching voltage
- adjustable current limiting
- wear-free semiconductor switches
- continuous operation
- overload-able up to 15 % at continuous operation
- including bypass-contactor
- floating contact

- LED-indications on the device for fault diagnosis and operating diagnosis

Electronic execution with operation element, serial interface for remote control and status indication; the soft starter shall be completely programmed.

Technical Data:

| | | |
|---|---|---|
| Motor nominal voltage | : | 3 x 433 V; 50 Hz |
| Rated motor output | : | at least 55 kW |
| (Auxiliary)Supply Voltage | : | 250 V AC |
| Degree of protection | : | at least IP 20 |
| Number of operations per hour | : | at least 10 |

**Mode of Operation:**

The soft starter shall be used for start / run up of the jet fans. After the sequence of starting the bypass-switch shall be activated. The soft starter and the bypass-switch shall be wired in a form, so that the motor of the jet fan also can be started using the bypass-switch in case of failure or the soft starter.

**9. Power Factor Correction**

Static power factor correction of suitable rating shall be deployed at the 415 V bus

The power factor correction shall ensure a power factor better than $\cos\varphi = 0.95$ ind.

Just low-loss, self-healing capacitors are allowed. The capacitors shall be equipped with an overpressure protection device. The capacitor losses shall not overstep the value of 0.2 W / kVar. Each capacitor shall be equipped with an according discharge device.

**10. Tests**

The panels shall be completely assembled, wired, and tested for operation under stimulated conditions to ensure accuracy of wiring, correctness of control scheme and proper functioning of all equipment. The LT switchboard shall be tested as per relevant standard at the factory in the presence of owner's Engineer.

The Bidder shall furnish copies of Type test certificates. Following type tests should have been carried out in certified Test laboratory during the period not exceeding 3 years from the date of opening the bid.

- short time current test
- Temperature rise test
- One minute power frequency voltage withstand test.

Following Routine Tests shall be carried out

- Mechanical operations test
- Dielectric tests.

### 7.2.7 Earthing System

**1. INTRODUCTION**

An Earthing System is a basic requirement of any electrical & electronics installation as it forms a primary line of protection for equipment and the operator. The object of an earthing system is to provide as nearly as possible a surface under and around a station which shall be at a uniform potential and as nearly zero or absolute earth potential as possible. The purpose of this is to ensure that, in general, all parts of apparatus other than live parts, shall be at earth potential, as well as to ensure that operators and attendants shall be at earth potential at all times. A well-designed low resistance earthing system is necessary for dissipation of heavy fault current and electrical surge to protect the equipment & user with minimizing the downtime, service interruption and replacement cost etc.

**2. SCOPE**

This document covers technical specification and designing for making Earthing Layout for Road Tunnel. The specification will cover the scope of work which will includes design, supply, installation and testing of Earthing Arrangement & its Components. The material offered shall conform to relevant standard with high quality and good workmanship capable to perform continuous and satisfactory operations in the actual service conditions at site.

The specifications will consist of the details of the Earthing Grid designed with Earthing Rod i.e. Copper Bonded Steel Rods, an Earth Enhancement Compound and permanent earthing joint solutions Exothermic Weld along with the procedure for constructing the earth pit for the maintenance free earthing system to ensure that the resistance to earth is near to acceptable values (<1Ω) throughout the life without any frequent maintenance or any replacement. The earthing system to be adopted for electronics equipment should be able to save the system components which are more susceptible to damage due to surge, transient and over voltage encountered due to various reasons.

## 3. REFERENCES

This specification will meet the requirements of mentioned documents & also working as a reference standard:

IEEE 80:2013 IEEE guide for safety in AC Sub-Station Grounding

IEEE 837 Standard for qualifying permanent connections used in substation grounding.

IEC 62561-7 Requirements for Earthing Enhancing Compounds

IEC 62561-2 Requirements for Conductors and Earth Electrodes

UL-467 Standard for Grounding and Bonding Equipment

## 4. EARTHING ARRANGEMENT FOR ROAD TUNNEL

All the earthing arrangement shall be interconnected with each other. Proper equipotential bonding shall be done. The earth resistance of the whole system shall be less than 1 ohm for-

1. Portal Substations
2. External Substations
3. Internal Substations/ Niches/E&M Niches
4. Control Room Stations

## 5. REQUIRED PARAMETERS FOR EARTHING GRID

ERT report for the soil resistivity values and to understand type of site

1. Fault Level for which grid shall be designed.
2. Duration of fault current to get earthed
3. Availability of Earthing area
4. Duration of Fault
5. Resistivity of Surface Material
6. Material of Earth Mat Conductor
7. Earthing Mat Geometry

## 6. EARTHING DESIGN FOR PORTAL SUBSTATIONS, EXTERNAL SUBSTATIONS & CONTROL ROOM STATIONS

An earthing grid with a combination of horizontal & vertical conductors along with exothermic welding joints shall be designed as per the fault current requirement and availability of area. The calculations shall be done using CDEGS software as per IEEE 80:2013. The earth resistance for the portal/external station grid shall be less than 1 ohm. Proper soil treatment is recommended in the areas of high soil resistivity using carbon based earth enhancement compound.

## 7. EARTHING DESIGN FOR E&M NICHES, NICHES, INTERNAL STATIONS & OTHER NICHES STATIONS INSIDE TUNNEL

An earth mat with the horizontal conductors shall be laid under the niches and the complete mat shall be interconnected with the portal/external stations earthing grid using the earthing conductor laid inside the tunnel so that the system will act as an integrated earthing system. The conductor sizing shall be done as per the fault current requirement as mentioned in IEEE 80:2013.

## 8. EARTHING DESIGN FOR TUNNEL BODY, S&T EQUIPMENTS INSTALLED IN THE TUNNEL

A conductor of suitable size shall be laid through the overall length of the tunnel on both the sides. At every crossing or at every 100-meter spacing (whichever is nearest) the conductor on the opposite sides shall be interconnected with each other for equi-potential bonding. Also, an equi-potential bus-bar shall be installed at every

crossing, which will again connect through these conductors. All the S&T equipments and other equipments shall be connected to these bus-bars for the earthing and equi-potential bonding.

For the tunnel body earth, the civil Concessionaire need to leave a point at every crossing for connecting the reinforcement of the tunnel with the earthing conductor for proper equi-potential bonding and for cathodic protection.

## 9. EARTH GRID DESIGN

Earthing System in an Earth Grid comprises of-

1. Horizontal conductor in the form of mesh
2. Vertical Earth Pit
3. Earth Enhancement Material
4. Exothermic Welding

## 10. EARTH MESH: COPPER/COPPER BONDED STEEL CONDUCTORS

An earth mat shall comprise of copper or copper bonded steel round conductors. The conductor shall be suitable to achieve calculated fault current. The manufacturer shall provide the conductor sizing calculation which shall be done as per IEEE 80:2013.

Based on conductor sizing calculation, the cross section of conductor is determined and the length of the copper conductor shall depend upon the required mesh size.

## 11. EARTH RODS: COPPER/COPPER BONDED STEEL SOLID RODS

The earth electrode/rod is the main component of the earthing system which is in direct contact with the ground and thus provides a means of releasing or collecting any earth leakage currents. The material should have good electrical conductivity and should not corrode in a variety of soil conditions. For an effective earthing system.

Acceptable earth resistance values: The acceptance earth resistance of an earth grid (Combination of Multiple Earthing connected in parallel shall be designed as per Soil Resistivity Report) shall be <1 ohm for power components & <1 ohm for electronics component.

## 12. Test Certificate and Approval for Copper/Copper Bonded Steel Conductors & Rods

- The laboratory test must be in accordance with IEC 62561-2:2018.
- As per IEC 62561-2, Earth rods shall be mechanically robust to ensure correct installation. The material of choice shall be sufficiently malleable to ensure that no cracking of the rod takes place during installation. It shall also exhibit good corrosion resistance.

## 13. EARTH ENHANCEMENT COMPOUND

Role/ Need of Earth Enhancement Compound:

As per IEEE 80: 2013, clause 14.5, Pg. No.- 78, “It is often impossible to achieve the desired reduction in ground resistance by adding more grid conductors or ground rods. An alternate solution is to effectively increase the diameter of the electrode by modifying the soil surrounding the electrode. Thus, the Ground Enhancement Material are typically placed around the rod in an augured hole or around grounding conductors in a trench, in either a dry form or premixed in slurry”.

As per IEC 62561-7:2018, clause 4.3, Pg. No. 8, “the material of the earth enhancing compound shall be chemically inert to subsoil. It shall not pollute the environment. It shall provide a stable environment in terms of physical and chemical properties and exhibit low resistivity. The earthing enhancing compound shall not be corrosive to the earth electrode being used.

Earth enhancement material is a superior conductive material that improves earthing effectiveness, especially in areas of poor conductivity (rocky ground, areas of moisture variation, sandy soils etc.). It improves conductivity of the earth electrode and the ground contact area. It shall be tested and confirm to the requirements of IEC 62561-7 having the following characteristics: -

i. RoHS tested Earth Enhancement Compound tested by NABL accredited lab in compliance to IEC 62561-7 with a resistivity some with a resistivity of 0.12 ohm-m.

ii. An earth enhancing compound shall be tested for Leaching Test, Corrosion Test, and Resistivity Test & Sulphur Test as per IEC 62561-7.

iii. It shall be a carbon-based material and shall be free from bentonite and other hazardous substances. It shall be permanent and offers +25 years of life.

iv. It shall be a non-corrosive material which does not leach out any chemicals into the ground. It shall retain moisture even in high soil resistivity areas. It shall lower an earth resistance value and shall offer a constant desirable performance.

v. Shall be carbon based with min 95% of fixed carbon content premixed with corrosion resistant cement to have set properties.

vi. Shall have high conductivity, improves earth's absorbing power and humidity retention capability.

vii. Shall be suitable for installation in dry form or in a slurry form.

viii. Shall not depend on the continuous presence of water to maintain its conductivity.

ix. Shall be permanent & maintenance free and in its "set form", maintains constant earth resistance with time.

x. Shall be thermally stable between -100 C to +600 C ambient temperatures.

xi. Shall not dissolve, decompose or leach out with time.

xii. Shall not require periodic charging treatment nor replacement and maintenance.

xiii. Shall be suitable for soils of different resistivity.

xiv. Shall not pollute the soil or local water table and meets environmentally friendly requirements for landfill, shall not be explosive & shall not cause burns, irritation to eye, skin etc. In this regard "Safety Data Sheets" shall be submitted by the manufacturers.

xv. Marking: The Earth enhancement material shall be supplied in sealed, moisture proof bags. These bags shall be marked with Manufacturer's name or trade name, quantity etc.

**14. Test Certificate and Approval for Earth Enhancement Compound**

i. The laboratory test must be in accordance with IEC 62561-7:2018.

ii. The compound shall be tested for Leaching Test, Sulphur determination Test, Resistivity Test, and Corrosion Test.

iii. Earth enhancement compound shall be tested for ROHS Restrictions of Hazardous Substances.

iv. As per IEEE 80, the compound shall be carbon based and shall have resistivity less than 0.12 Ω-m.

**15. EXOTHERMIC WELDING SYSTEM**

i. Electrical jointing or connection reliability is critical to the long-term integrity of the electrical system. Over the period of time, due to ageing, less maintenance and changing weather conditions the joints are becoming low performing joints as it gets corroded or loosen due to temporary jointing techniques.

ii. Recommended by IEEE 80, BS 7430, NBC 2016, an exothermic welding system is used for making electrical connections of copper to copper, copper to steel or copper to cast iron for grounding and cathodic applications. An exothermic welded connection shall be suitable for exposure to the elements of direct burial in earth or concrete without degradation over the lifetime of the grounding system.

iii. An Exothermic Welding System complying IEEE 837, has come up as a robust solution for these problems. Today, Exothermic Welding is a globally accepted method to make reliable and safe connections between two or more conductors. This technology is highly portable and does not require any external source of heat to make a joint offering in permanent molecular bonding among metallic conductors.

iv. All the buried joints shall be exothermically welded.

v. The molecular bonding shall offer complete surface contact hence an electrolyte cannot penetrate between the conductors which provide integrity to the joints.

vi. Testing of Exothermic Welding: - The laboratory test must be in accordance with IEEE 837.

### 7.2.8 Distribution / Sub-Distribution Boards

**1. Scope**

This specification covers Design, engineering, manufacturing, testing, supply, delivery, erection, installation, testing & commissioning of triple pole and neutral out door Type, Out Door Installation, Minimum IP 54, (TPN) Distribution

feeder pillar suitable for 415 v AC 3 Phase 4 wire system as per ISS: 5039 /8623/1977 with latest amendments, if any.

**2. Standards**

The distribution feeder pillars shall conform in all respect to the relevant Indian /International Standard specification, with latest amendments thereof; some of them are listed below.

| Indian standard | Title |
|---|---|
| IS- 5039 | Distribution Feeder Pillars |
| IS -8623/1993 | Low Voltage Switch gear and Control gear assemblies |
| IS-13947 | Degrees of protection provided by enclosures |
| IS-5/1961 | Specification for colours for ready mixed paints |
| IS- 11353 | Guide for uniform markings and identification of conductors and apparatus terminals |
| IS-6005 | Code of Practice for Phosphating of iron and steel |
| NFPA 502 | Standard for Road Tunnels, Bridges, and other limited Access Highways |

Material conforming to other internationally accepted standards, which ensure equal or higher quality than the standards mentioned above would be acceptable. In case the bidders who wish to offer materials conforming to the other standards, salient points of difference between the standards adopted and the specific standards shall be clearly brought out in relevant schedule. Four copies of such standards with authentic English translation shall be furnished along with the offer.

**3. Construction**

Feeder Pillars shall be suitable for outdoors installing and to have maximum protection from inclement weather. It should have compact construction with a degree of Protection IP-55 in accordance with IS-13947 with latest amendments.

FP & SP shall be made out of sheet steel of minimum 2 mm thick with proper support members so as to make it robust in operation. Bidders can also offer heavy gauge fire resistant poly propylene (FRPP) enclosures of thickness not less than 4mm for body frame and 2.5 mm for door panel.

Suitable mild steel reinforcement (frame) shall be provided which shall be coated with FRPP.Then the body of box shall be casted over the steel reinforcement by suitable mould

The FRPP panel shall be rodent proof, fire retardant and UV stabilized.

**4. DOORS**

Double –hinged doors should be provided on front as well as on rear to enable installation and inspection of cable connections and other equipment. Three heavy duty inside hinges shall be provided per door leaves. The design shall permit the doors being completely removed when necessary.

**5. LOCKS**

The front and back doors should be fitted with separate 65mm size MS locks (with special keys) such that unless door is closed (both leaves) it cannot be locked and unless it is locked, key cannot be out.

**6. CANOPY**

It should so be sloping so that rainwater does not accumulate. The canopy should extend beyond the feeder pillar body to avoid any rainwater falling inside the pillar.

**7. MOUNTING**

To mount on brick cement concrete plinth. the construction of the plinth is included in the scope of work.

**8. APRON**

Lower part should be made of angle iron reinforcement of 50x50x6 mm frame work (coated with FRPP) of 300 mm height covered with 315mm. Thick FRPP panel on all side s and bottom.

**9. ANGLE IRON STAND**

The apron shall be mounted on angle iron stand. The stand should be of angle iron 75x75x6mm (coated with FRPP) to provide strong supporting structure to the shell.

**10. Weather Proofing and Ventilation**

The canopy shall project over the side and doors and sides shall be lower than the top of side section of the shell to avoid ingress of water.

The side section shall be folded to form a water drawing channel for easy drainage of water through the sides and not through front or back.

The angle section shall project above the sides section to provide a gap (3.0mm between the), section and canopy to facilitate ventilation.

Ventilation Louvers cell type ventilation louvers covered with welded mesh screen and filter inside section of the shell.

**11. 3.8.11 Bus Bars**

Bus bars should be in one piece for each phase and neutral of electricity. Aluminium of size 50x12mm, (or as per the current capacity with current density as 0.7 A/sq.mm) PVC sleeved /taped suitable with red, yellow and blue for the phase and green for neutral. All live joints shall be PVC taped. All bus bars taping and markings shall be in accordance with IS-11353. The bus bars should be mounted on insulators and fixed with riveted joints. Hylam barriers between the bus bar of each phase and between the bottommost phase and the neutral shall be provided. The bus bars should withstand thermal stress and dynamic forces in the event of short circuit and it should be supported and arranged so as to withstand any damage or deformation at specified short time current of 36KA for one second as per IS-5039/1983 with latest amendments.

**12. Circuit Ways**

The configuration of Distribution/Sub-Distribution Boards shall be as per the detailed design of the Concessionaire, subject to approved of the Independent Engineer.

**13. Earthing**

Earthing shall be provided with two separate earthing terminals on its casing on either sides of the apron over and above all other means of earthing (i.e. earthing through armouring of current carrying cables).The earth terminals shall be complete with galvanized bolts, nuts and washers of size 6 x20mm.

The terminals shall be identified by means of proper sign marking in legible manner adjacent to the terminal.

One aluminium earth bus bars shall be provided with suitable holes and nuts and bolts for connecting cable armouring to earth through it. The connection shall be through cable sockets to be provided. The size of the earth bus bar shall be 250 sq. mm and material shall be electrolytic aluminium.It shall be running along the feeders pillar from one end to the other and connected to then earth terminals at the ends .

**14. Pillar Lighting**

A lamp holder and CFL lamp complying with IS -1258 operated by an internal piano switch a service fuse in the lamp circuit shall be fitted in each pillar for internal illumination .in addition a 3- pin 15 A plug and socket Shall Be Provided With A Switch.

**15. Danger Plate**

An enameled sheet danger plate of approved design shall be fixed on the front and rear doors of the pillar.

**16. Iron Casings**

All angle iron/reinforcement shall be coated with FRPP.

**17. Tests**

Verification of temperature rise limits as per IS-8623

Verification of short circuit strength at 40KA for one second as per IS -5039/1983/3623/1977 with latest amendments.

Verification of degree of the protection as per IS -13947 with latest amendments.

**ROUTINE TESTS**

Feeder pillars shall be subjected to following tests as per IS.

i. Verification of dielectric properties with test voltage 2.5 KV rms for one minute between:

- Poles
- Poles and neutral
- Current carrying and non- current carrying metal parts.

ii. Insulation resistance test between poles and body should be minimum 50Mega ohm

iii. Continuity test by providing incoming 3 phase supply and checking the Power availability on the outgoing and feeder circuits.

**18. Foundation For Distribution Boards**

The Concessionaire shall submit the design of foundation of pillars for approval of client/consultant The pillar shall be mounted on brick cement concrete plinth foundation.

Finish level of foundation shall be 50 cm above ground level.

No foundation is necessary for steel tubular pole ( 1/6th pole length shall be buried inn the ground ) but it needs muffing with cement concrete upto 100 mm below ground and 150 mm above ground.

**19. Earthing of Distribution boards**

The distribution feeder pillar and the service pillars shall be earthed and such earthing is a part of the scope of work. Earthing shall also conform to the provision in design criteria and the attached earthing arrangements.

### 7.2.9 Tunnel Lighting

The Concessionaire shall design, supply and install a complete lighting system of the Portal building. All luminary es, fittings and accessories shall only be proprietary type. The Concessionaire shall lamp in all luminaries verify the correct operation before completion. Emergency supply shall be connected to the lighting in the Portal Buildings.

The Concessionaire shall provide the following:

1. lighting switches.

2. Dimmers.

The Concessionaire shall mount luminaires on proprietary supports by means of battens, trims,

tilize, roses or packing material to suit the location. The lighting system shall tilize 2x2.8W fluorescent lighting with electronic ballasts.

**1. Scope of Work, Terminal Points & Exclusions**

The scope of work for the "Tunnel and Road Lighting System" and associated items covered under this specification, shall include but not limited to the items / requirements specified in the subsequent sections.

Engineering, design, manufacture, assembly, shop testing including type tests as per IEC 60529, IEC 60598, IEC 62384, IECNA LM 79, ANSI 8750 at manufacturer's works.

- Providing all labors, materials and equipment for factory testing.
- Special tools and tackles, as required, for operation and maintenance, inspection and repair of the equipment / systems offered.
- All materials supplied under this contract shall be new and unused.

Services Under Scope of Supply

- Inspection and expediting, handling, packing, forwarding, transporting to site, documentation including submission and approval of drawings.

- Engineering of all the systems covered in this specification, including preparation and submission of detailed based on codal requirement specified in IRC SP:84 2014, IRC SP:91 2011, CIE 88: 2004 and MORTH Guidelines for Tunnel and quantification of entire items included in the scope.

Scope of supply and services of basic equipment

- This section details out the scope of supply and services for "Tunnel and Road Lighting System" with associated auxiliaries. Components and services not specifically mentioned here but necessary to complete the work in all respects, regardless of any omission in this specification or drawings, is deemed to have been included in this section.

- Submission of Lighting layout for Tunnels and Road portion covered under the complete project stretch and approval of drawings.

- Submission of inputs regarding operating philosophy, design of circuit distribution scheme and any other inputs for completion of lighting system detailed engineering.

- The design, manufacture, Factory Acceptance Test (FAT), transportation to site, Site Acceptance Test (SAT) and Supervision of Erection, testing and commissioning of the complete Lighting System for Tunnel and Road.

**2. Spares**

The SUPPLIER shall include the commissioning spares along with the equipment for replacement of damaged or unserviceable parts during the execution of the project at site. The SUPPLIER is expected not to fall back on the PURCHASER from their stocks (for such replacements) which are meant for two (2) years of trouble-free operation after the equipment are taken-over.

Terminal Points

- LT Power - 230 V, 1 Ph : At the terminals of light fittings

Exclusions

- Cabling
- Lighting Distribution Boards
- Installation

SPECIFIC REQUIREMENT OF ILLUMINATION SYSTEM

The luminaries shall confirm to IS 2149-1970, IS 1913-1978 and 1944-1970 (parts I and II). The luminaries shall be totally enclosed, dust and watertight, shock resistant and specially designed to house the specified lamps, electrical gear and accessories. The body shall be made of dust painted stainless steel.

- The colour of all lamps shall be Natural White 4000 K.
- The colour rendering index Ra shall be ≥ 80.
- Luminaire/system efficacy (incl Optical and driver efficacy) shall be > 124 Lm/W
- Electrical Insulation shall be Class I or Class II
- IK rating shall be IK 08
- Fittings shall be with ingress protection of IP 66.
- System Surge Protection shall be 6/10kV
- The life span shall not be less than 50,000 hours.
- Higher efficiency long life LED shall be envisaged.
- Free from UV and IR radiations.
- LED Driver Specification

- Input operating voltage shall be 200-260 V.
- Electronic control gear shall be with THD ≤ 10%.
- The power factor shall be better than 0.95.

- Power efficiency shall be greater than 85%.

Other Parameters

- Working humidity shall be 10% - 90% RH.
- Working temperature shall be between -40 to 55 Deg C.
- All light fittings shall be of waterproof and Corrosion proof.
- Fitting shall be suitable for connection to LSOH type cable
- Higher rated lamps shall be provided with aluminum heat sink body with fins for better heat dissipation.
- Epoxy powder coated aluminum channel housing shall be provided for all tube light fittings
- The mounting brackets shall be made from stainless steel and have longitudinal slots for horizontal and vertical adjustment. The minimum numbers of mounting brackets are four per luminary.
- Phase selection shall be possible at the terminal blocks without any further modification of the wiring inside the housing/luminary.
- The housing shall be suitable for mechanical cleaning.
- BIDDER shall have to select suitable light fittings to suit Tunnel Threshold Zone, Transition Zone, Interior Zone, Exit Zone, Cross passages, E&M Niches, Lay Bye and Road illumination level calculated based on codal requirement as specified in the document. Lth Values to be considered for Illumination Level calculation for tunnels.
- No light shall be directed with flow traffic to avoid shadow effect.
- Drawings & Documents to be submitted along with the bid document:
- Illumination level calculation for each Tunnel
- Layout arrangement along with type fittings for each Tunnel
- Catalogue details of offered light fittings with technical specification
- Drawings related to High Mast pole & its Junction boxes.
- Tunnel wise power consumption
- Type Test Certificates
- Quality Assurance Plan

**EMERGENCY LIGHTING**

Design, supply and install a complete operational emergency evacuation lighting system ,

tested and commissioned in accordance with IEC/ISO standards for emergency lighting.

for the Portal Buildings and Central command and control Center

Visual indicator lights: Provide a red indicator, readily visible when the luminaire is in its

operating location, which indicates that the battery is being charged.

Inverter system: Provide protection of the inverter system against damage in the event

of failure, removal or replacement of the lamp, while in normal operation.

Local test switches: Provide a momentary action test switch, accessible from below the

ceiling, on each luminai re to temporarily disconnect the mains supply and connect the

battery to the lamp.

Common test switches : Provide a common test switch on the distribution board w. hich

disconnects main supply to the luminaries and..tests for discharge performance, after

testing; this switch must automatically revert to normal operating mode.

Type: Lead-acid or nickel-cadmium batteries capable of operating each lamp at its rated

output continuously at least 2 hours during completion tests and 1.5 hours during

subsequent tests. ·

Battery life: At least 3 years when operating under normal conditions at an ambient temperature of 25°C and subjected to charging and discharging at 6 monthly intervals.

Marking: Indelibly mark each battery with its date of manufactu re. ,

General: Provide an unswitched active supply to each luminaire and extt sign, originating from the test switch control panel.

**VOICE/DATA CABLING AND COMMUNICATIONS SYSTEM**

Design, supply and install a complete voice/data communications and cabl ing for the Portal Buildings. Provide a complete operational telecommunications cabling system, tested and commissioned in accordance with ISO/IEC standards for category 6 communications cabling systems. Provide accommodation for telecommunications cabling infrastructure complying with ISO/IEC standards. Include the following:

A) 45 RU cabinet complete with patch panels and power rails supplied from the UPS

B) Switches equal to HP or. Cisco

C) Office server (refer PMCS section for details on server)

D) Category 6 voice/data cabling to RJ45 outlets

E) Patch leads

F) Individual workstations shall be provided by the OMCS Concessionaire. ;

Application Class

Application class to ISO/IEC standards for calegory 6.

Conformance: Certify the design and installation for conformance with ISO/IEC standards.

System warranty: Warrant the specified communications cabling performance for a minimum of 15 years.

Records

Record book: Provide a record book at each cross connect.

Records in pencil: Complete the records in pencil for each termination and jumper, providing origin and destination and type of service.

Location: Secure log books in each distribution frame records holder. Identification and labelling, and record documentation:

Cable separation

Low voltage cables: Separate telecommunications cables not enclosed in conduits or ducts from low voltage services by at least 150 mm.

Electromagnetic interference (EMI): Provided clearance to minimise the effect of EMI where communication cables are installed parallel and adjacent to power cables carrying loads in excess of 200 A.

**Installation**

Crossover: Install cables neatly and without crossovers between cables.

Loom size: Loom cables into groups not exceeding 50 cables, and hold looms in place using reusable cable ties at least 20 mm wide. Do not exert compressive force on the cables when installing cable straps.

Cable insulation and accessories will be Low Smoke Halogen Free, in tunnel and

approach areas.

Outlets

Outlets: Provide RJ45 8-way modular jacks.

Pinouts: The pinouts vary with the application. Determine required pinouts before making

cable terminations.

**Fly leads**

General: Provide fly leads to 50°(o of the outlets installed.

Earthing

Communication earth system (CES): Provide a communications earth terminal (CET)

associated with the local protective earth (PE) system adjacent to each electrical

distribution board.

### 7.2.10 UPS Emergency Power Supply

#### 1. General

This article covers the UPS emergency power supply of all required equipment, materials, accessories, and all labour for the complete emergency power installation.

The Uninterruptible Power Supply in Control Buildings shall feed the following system:

- All surveillance equipment
- Fire detection system
- Data transmission equipment
- Emergency Tunnel Lighting
- Control systems

#### 2. Scope of Work

The UPS shall include the delivering of material, feeders, complete installation, commissioning, tests and equipment of the following:

- Lighting UPS at portal ends at ___ kVA(N+1) and inside tunnels at __ kVA(N+1) of virtual power over a period of 120 minutes for tunnel loads.
- Critical Power UPS at portal ends at ___ KVA(N+1) and ____ KVA(N+1) respectively and ___ kVA(N+1) inside tunnel shall provide virtual power over a period of 30 minutes.

The UPS has to be fed from the main power supply (433 / 250 V, 50 Hz) and shall supply the connected equipment via rectifier, battery and inverter.

In the event of a main power supply failure the equipment has to be fed from the battery and inverter system without any interruption.

The UPS shall be equipped inclusive bypass switch and an interface for Telecontrol System.

#### 3. Technical Specification (Ups Components)

**INVERTER BATTERY BANK**

**Batteries:**

i. Maintenance-free NiCd (Nickel Cadmium) power batteries of voltage as required by the UPS-system.

ii. The battery capacity at the following stations shall ensure supplying the needed load for at least 60 minutes.

iii. Batteries shall be of rugged design in order to provide a heavy-duty operation of at least 10 years with low internal resistance and minimal maintenance.

iv. Allowed temperature range: 15° to 30° C

v. Interconnection Bus Bars:

vi. The bus bars shall be made of copper according to the relevant standards, mentioned herein.

vii. Suitable size to provide a minimum voltage drop

viii. PVC clad to provide protection against accidental contact.

ix. Battery Stands / Racks:

x. The batteries shall be mounted on steel racks to provide a compact arrangement, with easy installation and access for servicing.

xi. The racks shall be made of steel with electro statically deposited powder coating.

xii. The coating shall be resistant against acid, saline and highly resistant against scratching and / or impact.

xiii. All other required materials shall be highly resistant against environmental conditions as experienced in battery rooms.

xiv. An electric ventilation and climate shall ventilate the battery room. The complete air shall be changed a minimum of five to six times per hour.

**RECTIFIER / CHARGER UNIT**

i. This unit has to be equipped with output current limiting, whereby the maximum output current shall be limited to 125 % of the nominal output current rating.

ii. This current limit shall be adjustable from 100 % up to 125 %.

iii. Power semiconductors in the rectifier / charger unit(s) shall be fused with fast blowing fuses, so that a loss of any one-phase semiconductor shall not cause cascading failure.

iv. Each fuse shall be controlled by a fuse monitoring circuit leading to an indicator light on the UPS's control panel as well as to a common fault indication.

v. The output filter shall minimize the ripple of the current in the batteries. Under normal conditions the ripple of the current in the battery shall exceed 3% RMS.

vi. The filter shall be adequate to ensure that the DC output of each rectifier / charger shall meet the input requirements of the inverter.

vii. The UPS shall have the capability of operating the inverter directly from the rectifier with the batteries being disconnected.

viii. Quick charging equipment shall be capable of charging fully discharged batteries within six hours.

ix. Input: 433/250 VAC, 3-phase, 4 wire, 50 Hz +/- 2 %

**4. Inverter Unit**

Input: Output from the rectifier / charger unit (batteries).

Output: 433/250 V sinusoidal AC.

Maximum of total harmonic distortion: +/- 1 % at power factor 1 from no-load operation to full load.

50 Hz +/- 1 % at power factor 1 from no-load to full load.

Maximum dynamic Voltage deviation: +/- 5 % during power failure +/- 10 % during major load change.

Recovery to a maximum deviation of +/- 3 % within 50 ms and to +/- 1 % within 100 ms.

Total harmonic Distortion:3 % maximum

The rectifier shall be able to operate 10 minutes at 125 % overload at power factor 1 after the working temperature has been stabilized at the nominal workload.

Under normal conditions, the surrounding temperature will not exceed + 40 °C.

A self-protecting current limiting circuit shall limit the inverter output to 125 % of the rated load or respectively in case of a short circuit.

Constant synchronization of the oscillator shall define the converter frequency and its stability during stand-alone operation.

During normal operation, the inverter shall be synchronized by the main supply. In case of mains failure or frequency-deviation larger than +2 % / -1 %, the inverter shall automatically switch-over to its interior oscillator.

Upon return of main supply, resynchronization shall be started automatically. Resynchronization at full load and / or full voltage shall be achieved within 30 seconds.

The deviation from 50 Hz shall never exceed +/- 1 Hz.

The power semiconductors of the inverter shall be fused with fast blowing fuses to prevent cascading failures.

Each fuse shall be controlled by fuse monitoring circuit leading to an indicator light on the UPS's control panel as well as to a common fault indication.

**5. Protective Devices and Filter Circuits**

A DC (direct current) smoothing equipment shall enable the system to achieve a total harmonic distortion, which isn't larger than 3 % RMS of the output.

Protective devices shall avoid any damage or failure on the UPS caused by excessive overload, short circuits, high voltages caused by lightning activity and/or other conditions.

**6. DC Circuit Breaker**

The UPS shall contain a DC circuit breaker. If open, the battery shall be completely disconnected from the rectifier / charger and the inverter.

**7. System Bypass Switch**

The UPS system shall be by-passed automatically in case of overload. The static switch detection and transfer time shall not exceed 5 ms.

**8. Static Transfer Switch**

The static transfer switch shall be equipped with a manual selector switch to allow manually controlled switching between the UPS and the bypass source for maintenance and service purposes.

The static transfer switch shall be rated higher (power, respectively current) than the inverter current limiting rate and shall have a short circuit current and time rating equivalent to the fault level of the bypass source at the static transfer switch.

**9. Auxiliary Equipment**

- Emergency flash light with battery charger installed in the battery room.
- All facilities required for handling of acids and gasses.
- Warning notices concerning the handling of the whole UPS system in English language.
- Working instructions for UPS

Warning notices and working instructions shall be in two separate and properly indicated pockets on the inside of the UPS switchboard as well inside the battery room.

**CABLING**

Cable dimensioning shall be in accordance to the relevant standards and shall have a diameter that the voltage drop is not more than 10 % to the nominal voltage from the transformer to the furthest supplied electrical facility. Also the cables shall have such a diameter that, if there is a short circuit at the furthest point to the circuit breaker, the circuit breaker cuts off without the cable exceeding its rated temperature.

**MAINTENANCE**

The emergency power supply shall be designed for continuous reliable operation such that the "Mean-Time-Between-Failures" (MTBF) for individual modules of the UPS through the rectifier / charger unit, inverter unit and static switch etc., shall be more than 80,000 hours.

To ensure a minimum down-time, the "Mean-Time-To-Repair" (MTTR) of the emergency power supply shall not exceed 24 hours for the UPS.

The MTTR shall be the time, excluding travel time, required to diagnose the fault and restore the emergency power supply to normal working condition by means of modular replacement at the tunnel site.

The travel time must not exceed 12 hours.

### 7.2.11 Erection, Testing & Commissioning of Electrical Equipment

#### 1. Scope

This section covers the procedures & recommended practices for erection and commissioning of Electrical Works at Tunnel & auxiliary equipment, accessories, associated civil works & other materials for the commissioning.

a) Indian Electricity Rules.

b) Tariff advisory committee

d) IS-6600: Code of practice for installation and maintenance of Transformers.

e) IS-3043: Code of practice for earthing

f) IS-7098: Code of practice for installation and maintenance of cross-linked polyethylene insulated PVC sheathed cables.

g) IS-2309: Code of practice for protection of building and allied structures against lightning

h) IS-732: Code of practice for electrical wiring installation

i) IS-6665: Code of practice for industrial lighting

#### 2. Transports for Erection

The Concessionaire shall provide, at his own cost and expenses, all labour, plant and materials necessary for unloading and erection at site and shall be entirely responsible for its efficient and correct operations. The Concessionaire shall setup his own material stores for the storage of all materials maintained by their qualified store personnel.

The Concessionaire is responsible for all the transport facilities, loading gauges and ensure that the equipment required to be transported shall conform to these limitations. The Concessionaire shall also be responsible for verifying the access facilities required for the transportation.

#### 3. Erection Work

The installation shall be carried out by an electrical Concessionaire holding a valid license & grade as required by the State Government. The successful bidder shall provide particulars of the license held by him (or) his Sub Contractor to the purchaser. The installation shall require approval of the Chief Electrical Inspector and it is the responsibility of the Concessionaire to get this approval and the purchaser shall provide necessary assistance in this connection. The Concessionaire shall also fully assist the purchaser in obtaining approval from any other statutory authority, if necessary, for the successful commissioning of the township.

Any modification in the equipment or installation that may be demanded by the inspector shall be carried out by the Concessionaire at no additional cost to the purchaser.

In accordance with the specific installation instructions as per the manufacturer drawings or as directed by the purchaser, the successful bidder shall unload, erect, assemble, install, wire, test and commission all electrical equipments included in this contract. Equipments shall be installed in a neat workman like manner.

Erection materials, tools, tackles, crane, rigging items, testing instruments or any other machinery required for erection shall not be supplied by the purchaser. The successful bidder shall arrange for the same in a timely manner and shall not be allowed to claim for any delay or extra cost of any nature.

Consumable materials of any nature required for the erection job shall also have to be arranged by the successful bidder.

Clearing the site after completion of erection as well as regular clearance of unwanted materials from site, returning all packing material and excess material supplied by Purchaser back to Purchaser's stores shall also be covered under the scope of work. Any damage done to buildings, structures and plant (or) property belonging to the purchaser and their parties shall be made good at the Concessionaire’s expense.

All equipment and instruments of indoor and outdoor type shall be inscribed with number, nomenclature, Danger Boards and other instructions.

The successful bidder shall do touch up work on the surface of equipment, which are scratched and/or damaged during transportation and erection. The paint used shall match exactly with the surface being touched up.

The successful bidder shall employ skilled and semi-skilled labourers for erection & installation testing as required.

All Electricians, cable jointers, wiremen, welders and others employed shall be suitably qualified possessing valid certificates / licences recognized by the competent authorities.

The successful bidder shall also furnish a list of Engineers / Supervisors and staff employed by him for erection and installation jobs, giving in brief, qualification and experience of such staff and indicating whether they hold such competency certificates / licenses to supervise the electrical installation jobs as required under Indian Electricity Rules & State Electrical Inspectorate Rules.

The successful bidder shall set up his own workshop and other facilities at the allocated place at site to undertake fabrication jobs, pipe bending, threading etc.

The successful bidder shall be responsible for recording of all readings and observations during erection, testing and commissioning, in registers or in prescribed Performa. These shall be carried out in the presence of Purchaser's representative. All such test data and records shall be duly signed by the successful bidder's Engineer and Purchaser's representative and shall be submitted to Purchaser in triplicate.

## 4. Equipment Erection

The Concessionaire shall assemble, install and connect all the equipments with all accessories including terminal clamps, with proper alignment required to complete the job and these shall be as per equipment manufacturer’s instructions. Equipments shall be erected with proper clearances from nearby walls / other equipments / beams / column etc as per statutory requirements.

The Electrical equipment shall be done by tools & tackles as recommended so that no injury is made to the equipment. The handling during erection shall be done as per best erection practices using the necessary tools & other required materials like Vanila ropes, wooden supports etc.

## 5. Erection of Steel Structures / Poles

The Concessionaire shall Supply, fabricate and carryout erection of all steel structures required to mount the equipment, gantry structures, lightning mast, any other miscellaneous supports required to complete the job with proper alignment designated on drawings duly approved by the Independent Engineer.

Structures shall be erected on foundations until atleast 14 days after placing of the concrete in foundations. All structures shall be strictly fabricated as per drawings.

The nut & bolted type structure shall be assembled & proper tension with torque ranches shall be applied as per recommended torque charts for each type & size of bolts.

The Structure shall not be welded and if required in exceptional case, proper paint shall be applied, preferably Zinc Rich Paint or Aluminum paint of proper coat shall be applied to the satisfaction.

Control interlocks shall be provided in order to prevent the inverter from being manually switched back to the essential bus (main power) without synchronization.

## 6. Erection of HT Cable, Auxiliary Power and Control Cable

Concessionaire shall transport the cable to the installation location, laying, fixing, and terminating of cables to the required satisfaction of purchaser / consultant.

Cable laid shall be neatly dressed and clamped 1050 mm deep from the FGL. For buried cables, Cable route markers shall be installed along the cable route at every 30 meter interval, at all road crossings and joint locations.

Whenever cables pass through any floor or wall, suitable manhole/cutouts shall be made. The openings shall be sealed using suitable fire resisting materials to prevent the fire spreading.

Standard cable installation tools shall be utilized for cable pulling. Maximum pull tension shall not exceed the manufacturer’s recommended value. Cable grips, rollers or pulleys used shall be properly lubricated. The lubricant shall not injury the overall covering and shall not set up undesirable conditions of electrostatic stress.

Sharp bending of cables shall be avoided. The bending radius for various types of cables shall not be less than those specified by manufacturer.

Where groups of HV, LV and control cables are to be laid along the same route, suitable barriers to (physically) segregate them shall be employed.

Where cables cross roads, water, oil, gas or sewage pipes, the cables shall be laid in reinforced concrete pipes. For road crossing, the pipe for the cable shall be buried at not less than one metre depth. Cable shall be protected at all times from mechanical injury and from absorption of moisture.

Cable that are directly buried in ground at 1050 depth from the FGL. Keep Center to center distance two dimension (2D). (Refer the Road Section Drawing for Details)

Some extra length shall be kept in each cable run at a suitable point to enable one or two straight through joints to be made at a later date, if any fault occurs.

Cables shall be laid in proper sequence so as to avoid unnecessary crossing of other cables upon entering or leaving a run of tray. Cable splices shall not be permitted.

Metal sheath and armour of the cable shall be bonded to the earthing system of the station.

Each cable shall be identified with its identification number as indicated in the drawing.

Cable clamps shall be of 3mm thick galvanised M.S. spaced at every 1.5 M interval.

Suitable cable aluminium tags shall be tied at every 30mtrs and at every bend along the cable length, when the cables run in bunches in the cable tray / trench / buried, for easy identification.

**7. Cable Supports and Accessories**

Cables supports shall be run in concrete trenches. Cable supports shall be installed in cable trench at 750mm interval when cable tray are not used and if cable trays are provided, it shall be supported at every 1 meter interval.

Cables shall be clamped to the cable supports in both horizontal runs and vertical runs by suitable site fabricated clamps.

All cable sleeves shall be sealed at the outlet of cables from the cable trench for protection towards entry of foreign particles.

**8. Erection of Lt Panel, Other Panels and DB:**

All panels & boards shall be installed on finished surfaces. The correct level shall be ascertained before final grouting.

The Concessionaire should take utmost care in handling delicate equipments, instruments and relays. Dragging shall be avoided as far as possible. Wherever the instruments and relays are supplied separately, they shall be mounted only after the associated control panels have been erected and aligned.

The Concessionaire shall also carry out the following: -

- Prepare a mounting base for equipment including leveling.
- The clearance on all sides of the panels shall be as per the drawing & shall comply local statutory conditions.
- Free movement of the breaker truck in each cubicle of interchangeability of breaker trucks shall be checked before final fixing of cubicles.

**9. Erection of Earthing System**

Concessionaire shall arrange for measurement of soil Resistivity at the award of contract of arranges to furnish earthing design calculation for purchaser / consultant approval. The Concessionaire shall submit earthing layout, equipment earthing details for approval. The entire earthing system shall be carried out inline with the specification and as per the approved drawings

The entire earthing of substation shall be carried out inline with the specification and as per the approval drawings.

**10. Concessionaires Tools and Equipment**

The Concessionaire shall provide all necessary tools and equipment that are required to complete the works. The Concessionaire shall also submit along with bid details of tools, tackles & equipments to be employed by them.

**11. Field Testing & Commissioning**

**a. SCOPE**

This part of the specification covers the guidelines for testing and commissioning at site of all outdoor and indoor electrical equipment covered in this package.

**b. STANDARDS**

The testing & commissioning covered by this specification shall comply with the requirements of the latest editions of Indian Standards / regulations.

The manufacturer's recommendations for testing and commissioning shall also be followed.

**c. GENERAL**

Tests as detailed shall be carried out in the field prior to commissioning tests to demonstrate that the equipment's performance guarantees are met, equipment are properly installed, correctly adjusted and suitable for commercial operation.

Tests shall include those specified and any other necessary to demonstrate compliance with the specification.

All testing kits / instruments used by the successful bidder shall be calibrated prior to commencement of the tests and the calibration certificate to be produced to the Engineer at site.

**d. GENERAL CHECKS**

The following physical checks shall be carried out on all the equipment.

- Check for physical damage
- Check for tightness of fixing bolts, nuts, clamps etc.
- Check for oil level and oil leakage.
- Check for air / hydraulic / gas pressure where ever applicable.
- Check for earth connections
- Check for cleanliness of insulators
- Check for name plate details as per specifications
- Any other physical check as recommended by equipment manufacturer / Indian Standards / Codes of practice.

**Outdoor panels**

- Check for proper fixing of all components as per G.A drawing and other relevant drawings.
- Check for tightness of connections.
- Check for continuity of wiring.
- Measurement of insulation resistance.
- Check for correct operation of closing and tripping devices, alarm annunciation, indications and interlocks as per relevant drawings.
- Check for meter and relay calibrations

**7.2.12 FIRE DETECTION**

**1. GENERAL**

This covers the complete fire emergency facilities (for detecting fire in and outside the tunnel, as well as equipment for firefighting), the whole automatic Fire Detection System (linear fire detection inside the main tunnel tube and sensors inside the equipment room & Niches (with E&M equipments)) including all required equipment, materials, labour and accessories. Also, all necessary accessories, required for transmission and indication of the given signal (potential free contact) at the Control Centre and Equipment Room shall be included in the scope of work.

All interface equipment which is necessary for the data-transmission to / from the Control Centre shall be included in the central connection element.

The observation of the tunnel is divided into two central units:

- Fire detection system (equipment room, Niches (with E&M equipments), substation Niches, Control Centre)
- Linear fire detection system (tunnel tube)

The whole fire detection system shall be proofed by an accredited laboratory. The Concessionaire shall hand over a protocol of this examination to the Client.

Any kind of fire detection equipment shall be supplied by the UPS-system.

**2. SCOPE OF WORK**

FIRE DETECTION SYSTEM

Fire detection unit with subunits in the tunnel tube

- With interface to linear fire detection system
- Manual alarm push button "FIRE" at the Niches (with E&M equipments) & equipment room
- Optical smoke detectors in the equipment rooms, control room (raised floor and ceilings)
- Alarm, control and indicating panel(s)
- Cabling for power supply, control, and monitoring
- Interface for corresponding automatic controls of the telecontrol system (SCADA) which distributes the command(s) to the CCTV System, the Control Centre, the Ventilation Control System, the Lighting Control System, etc.

LINEAR FIRE DETECTION SYSTEM

The linear heat sensor cable shall run through the tunnel tube and mounted on the ceiling of the tunnel tube.

The linear heat sensor cable shall be controlled by a linear heat detection unit. The detection units shall transfer the alarms to the main linear fire detection unit, and further on to the Fire alarm Control Panel in the equipment room / control room. From the Niches (with E&M equipment)/ equipment rooms / niches substation, the fire alarms shall be transmitted to SCADA.

The detection system shall measure the absolute temperature, the increase of temperature over time and shall hand over this information to the belonging linear fire detection (sub) unit. The linear fire detection system shall be able to check, if the rising of the temperature is caused by a fire, or if there may be a fault.

The linear heat detection (sub) unit shall determine the local temperature values as follows:

- Current absolute temperature.
- Increase (change) of temperature per minute.
- Temperature profile.

The time between registration of a fire alarm and activation of the necessary automatically operations shall take place within 1 minute.

The localization of fire shall be specified with an accuracy of 5 m.

Spurious / false alarms caused by temperature fluctuation shall be avoided by appropriate precautions.

The exact location of the linear heat sensor cable shall be defined by the manufacturer or the Concessionaire, as the exhaust temperature of the diesel locomotive can affect the detection of the cable.

LINEAR TEMPERATURE DETECTION SYSTEM/ LINER HEAT/ FIRE SENSING CABLES

- Linear Temperature detection central unit with subunits and temperature sensitive cabling
- Fire Alarm, control and indicating panel(s)
- Cabling for power supply, control and monitoring
- Interface to fire detection unit and further on transmitting of information to SCADA

## 3. FIRE DETECTION & ALARM SYSTEM

This section of the specifications includes the furnishing, installation, and connection of a multiprocessor controlled, intelligent fire alarm and integrated emergency voice evacuation system required to form a complete coordinated system ready for operation. The specification covers the complete fire protection System (for detecting fire in and outside the tunnel, as well as equipment for fire -fighting), the whole automatic fire detection system (linear fire detection inside the main tunnel tube and sensors inside the Electrical Control Station) including all required equipment, and accessories. Also, all necessary accessories, required for transmission and indication of the given signal (potential free contact) at the Control Centre SCADA and niche substation / Equipment Room shall be included.

- All interface equipment which is necessary for the data-transmission to / from the Control Centre (SCADA) shall be included in the central connection element.
- The observation of the tunnel is divided into following central units:
- Fire detection system with heat/ smoke detectors (Control room)

- Linear heat detection system (tunnel tube), the whole fire detection system shall comply with standards of accredited laboratory and shall be UL listed FM approved.
- Emergency Voice/ Alarm Communication / The intelligent fire alarm and emergency voice evacuation system.
- Emergency & Service Telephone System

The whole fire detection system shall be proofed by an accredited laboratory. The Concessionaire shall hand over a protocol of this examination to the Client and the intelligent fire alarm system shall comply with requirements of NFPA 72 / IS-2189:2008 Standard.

Any kind of fire detection equipment shall be supplied by the UPS-system.

**a. SCOPE**

It shall include, but not be limited to, intelligent alarm initiating devices, alarm notification appliances, auxiliary control devices, annunciators, and wiring as shown on the drawings and specified herein.

**b. TECHNICAL SPECIFICATION - DETECTION UNITS**

FIRE DETECTION UNIT AND SUB UNITS

The fire detection inside the tunnel tube, as well as for automatic fire detection at the Electric Control rooms, a fully electronic system shall be provided.

All optical smoke detectors (situated in the electrical rooms) and emergency MCP's shall be controlled/connected by a common fire detection unit and Intelligent analogue addressable Fire Alarm Panel located in Control Room. Each alarm from the MCP's and sensors (of the fire extinguishers in the fire extinguisher panels) shall be detected by the associated detection (sub) units. The detection subunits shall transfer the alarms to the main fire detection unit in the Equipment Room and further to SCADA.

Electronic Hooters and one central siren shall be provided.

Every evaluated fire alarm shall cause:

- Tunnel lighting of the whole tunnel tube shall be switched on automatically. The alarm shall be transmitted to the Control Centre.
- The appropriate tunnel ventilation fire program shall start automatically.
- The firefighting water pumps shall be switched on automatically to standby but shall be used only if required.
- All necessary information shall be displayed at the Control Centre and the control panel.

For automatic operation of tunnel, the Smoke/heat Detection System / Fire Alarm Panel shall be provided with an interface, giving potential-free signals whenever a fire-detection from the various detectors occurs.

The reset of a fire alarm is only possible directly at the appropriate fire detection unit in the Electric Control rooms/ equipment room.

All devices of the fire detection system shall be supplied by the uninterruptible power supply.

**c. FIRE DETECTION SYSTEM**

The main purpose of automatically activating a detection system in a tunnel is to trigger an alarm upon fire detection, which is relayed to a constantly attended location in order to organize prompt emergency response, including evacuation and firefighting. Automatic fire detection systems can also be used to trigger automatic fixed fire protection systems.

Different systems may be considered, ranging from standard smoke and fire detectors (ionic, optical), flame detectors (UV/ IR), laser beam detectors (smoke) and linear detectors (conductors in insulator), to highly sophisticated early detection systems based on air sampling and CCTV imaging software.

**d. FIRE SAFETY EQUIPMENT**

- Automatic fire detection system in tunnel
- Fire alarm system in buildings
- Emergency telephone niches

To ensure higher system reliability, automatic fixed water-based fire-fighting systems in conjunction with Manual hose-based fire- fighting system should therefore be installed in tunnels as part of an integrated approach to the management of fire and life safety, unless it can be proved that existing early fire detection systems, combined with efficient emergency response, are enough to ensure life safety and to adequately mitigate property loss in a given tunnel. This should be considered on a case-by-case basis.

**e. LINEAR FIRE DETECTION UNIT**

The linear fire detection unit shall be situated at S/S (Electrical/SCADA Control Station).

A fully electronic linear fire detection unit shall continuously detect the maximum temperatures, temperature gradients over time and temperature differences over the entire cable length. Therefore, optical time domain reflection method with computer-aided alarm analysis shall be used.

The detection units shall be self-monitored. In case of breakage or malfunction an automatic fault-message shall be given to the Control Centre.

The linear fire detecting system shall be able to check, if the rising of the temperature is caused by a fire, or if there may be a fault.

The linear fire detection system shall be able to differ between hot exhaust of the moving vehicle and a “real” fire. A running or parking vehicles shall not result in a fire alarm. Only systems are allowed which have past positive test procedures in road tunnels with vehicles. The results of the test procedures shall be provided.

An unrestricted software which parts the sensor cable in zones of about 100 m length, shall be used. In event of fire alarm, so-called hot spots shall be localized.

Also, programmable alarm-thresholds per zone shall be provided. To limit the possibility of a breakdown of the linear fire detecting system, the sensor cables shall be connected at both sides to a fire detecting unit. If the sensor cable is on both endings connected to detection units, a maximum length of about 4 500 m of each sensor cable is permissible as per manufacturers recommendations.

The information of the zone which contains to the fire alarm, the direction of fire-spread / - propagation as well as the size of fire shall be transmitted to the Control Centre.

Remote adjustment and monitoring/ testing e.g. from Control Centre shall be possible.

The linear fire detection units shall include the necessary power supply unit with all required voltages with surge suppressors. A display with 4 rows (displays the messages as plaintexts) and self-monitoring shall be included in the detection units.

The linear fire detection unit shall have an automatic microprocessor unit with control panel and indicating panel. The distributor of the linear fire detection unit in the electrical rooms shall be equipped clearly, so that the display of the fire detection unit can be seen easily.

The linear fire-detection unit shall have interfaces to the fire detection unit depending on the offered system.

The fire detection & alarm system shall include following, but not be limited to, intelligent alarm initiating devices, alarm notification appliances, auxiliary control devices, annunciators, and wiring as shown on the drawings and specified herein.

- Heat detection unit with subunits in the tunnel tube with interface to linear temperature detection system/Linear Heat Sensing Cables
- Manual Call Points (MCP) in the tunnel in proximity to the Electric Control Stations, at Tunnel/ portals.
- Optical smoke detectors in the Service Electric Control Stations (raised floor and ceilings)
- Fire Alarm, control and indicating panel(s), intelligent analogue addressable type
- Cabling for power supply, control, and monitoring, FRLS
- Interface for corresponding automatic controls of the tele-control system (SCADA) which distributes the command(s) to the CCTV System, the Control Centre, the Ventilation Control System, the Lighting Control System, etc.
- Inside the tunnel emergency push buttons “FIRE” shall be mounted at Niches (with E&M equipments) and panels installed in tunnel.

- All optical smoke detectors (situated in the electrical rooms) and emergency push buttons "FIRE" shall be controlled by a common fire detection unit.
- Each alarm from the push buttons and sensors (of the fire extinguishers in the fire extinguisher cabinets) shall be detected by the associated detection (sub) units. The detection sub units shall transfer the alarms to the main fire detection unit and further to SCADA
- Every alarm shall be indicated audio-visually at the Control Centre. After verifying the alarm (true / false) by the operator by using the CCTV-System (installed by the EPC Concessionaire), the operator manually forwards the alarm to the fire department, to evaluated fire alarm causes:
- CCTV camera of the affected area is connected to the alarm / video screen, for surveillance the incident.
- Tunnel lighting of the whole tunnel tube is switched on automatically.
- The alarm shall be transmitted to the Control Centre.
- The appropriate tunnel ventilation fire program is started automatically.
- The fire- fighting water pumps are switched on automatically, but only if required
- All necessary information is displayed at the Control Centre and the control panel in the Control Room s.
- For automatic operation of tunnel, the designer of the Fire Detection System has to provide an interface, giving potential-free signals whenever a fire-detection from the various detectors occurs.
- The reset of a fire alarm is only possible directly at the appropriate fire detection unit in the Equipment Room, or control room.

**f. EMERGENCY PUSH BUTTON "FIRE"**

The emergency push buttons "FIRE" shall be installed to enable a manual fire-alarm. They shall be placed at the following locations:

- At niche with E&M equipments & portal substation
- At every S/S
- One emergency push button "FIRE" beside the entrance door to a low voltage room of the equipment rooms, niches (with E&M equipments) & control centre.

The size of the housing of the FIRE push buttons shall be approximately 130 x 130 mm (w x h). Further on, the housing shall be made of red coloured aluminium, shall have a breakable glass front and a lockable door. The degree of protection of push buttons shall be at least IP 54.

All push-buttons bear the symbol for FIRE integrated on the housing. Also, an indication in Hindi and English shall be visible.

All push buttons shall be connected to the fire detecting loop via a coupling element. The coupling elements shall be included in the price of the push buttons.

**g. FIRE DETECTORS**

**OPTICAL SMOKE DETECTOR**

Optical smoke detectors, resistant against high humidity, shall be provided. The electronic device shall be sealed, shielded and highly resistant against electrical interference. Degree of protection: IP 43

Optical smoke detectors shall be installed:

- Detectors in Equipment room
- Detectors in raised floor in the low voltage rooms, control rooms and entrance corridors of the Electric Control Stations and Control Centre; with substructure for mounting on lower edge of the panels of raised floor.

The optical smoke detectors and the push buttons "Fire" shall be connected to the fire detection (sub) units with loops. The type of cabling depends on the used system "System-Cable".

**h. POWER CABLE THERMAL MONITORING MANAGEMENT SOLUTION**

DTS Power Cable Management Solution Combines All of These:

- Distributed Temperature Monitoring

- Asset Visualization
- Alarm Management
- Central Database
- Reporting & Analysis Functions
- Real Time Thermal Rating

Capabilities in one fully integrated solution package. It automatically detects hotspot locations, provides alarms if critical limits are exceeded, and produces a temperature profile report.

All data is stored in a central database and are available for reporting and analysis, see where the bottlenecks are and derive valuable information to make the best decisions regarding future power grid upgrades.

The alarm management signals when limits are exceeded and your assets are at risk. Sections of the cable route cab be flexibly defined as different zones; different alarm levels and type can be assigned to each zone.

The system offers a quick and easy overview of the thermal status of your circuit with an easy-to-use graphical user interface. Circuit layouts are mapped and the various sections are colorized according to the measured cable surface. Temperature graphs and hotspot tables are easily accessed.

**i. EMERGENCY MANUAL CALL POINT (MCP)**

The emergency buttons "FIRE" Manual call Points shall be installed to enable a manual fire-alarm. They shall be placed at the following locations:

One MCP in proximity to the entrance door to a low voltage room of the Electric Control Stations.

Further on, the housing shall be made of red coloured aluminium, shall have a breakable glass front and a lockable door. The degree of protection of push buttons in the tunnel tube shall be at least IP 54. In the Electric Control Stations a lower class may be used.

All MCP's shall bear the symbol for FIRE engraved on the housing. Also, an indication in Hindi, English and a local language shall be visible.

All MCP's shall be connected to the fire detecting loop via a coupling element.

**j. WIRING**

The transmission of data of the fire detection (sub) units runs via a single mode fibre cable (A-DF(ZN)2Y 12x12 E9/125). Only a few fibres are reserved for the Fire Detection System.

"Fire Survival armoured / unarmoured e-beam cables with annealed copper conductor having Cross linkable Low smoke zero halogen insulation / or protected with Fire Rated Glass Mica tape with low smoke zero halogen inner and outer sheath. Armoured cables should comply to BS 7846:2009 (latest edition) & unarmoured cables to BS-7629 (latest edition). Both armoured and unarmoured cables should meet fire performance circuit integrity test as per standards.

- Wiring for signal line circuits shall be 1.5 mm2 minimum and subject to the circuit load.
- Wiring for Notification Appliances circuits shall be 2.5 mm2 minimum and subject to the circuit load.
- Wiring for speaker circuits shall be 2.5 mm2 minimum and subject to the circuit load.
- Wiring for telephone circuits shall be 2.5 mm2 minimum and subject to the circuit load.

### 7.2.13 Integrated Tunnel Control Systems

**1. General**

This Specification describes the minimum standards of the Integrated Tunnel Control System (ITCS) for Tunnel Control Building & Tunnel network. The Works to be executed under the Contract include the design, development, manufacture, verification, delivery, installation, testing, commissioning (including integrated testing and commissioning) and technical support for a complete ITCS to fully integrate the control, monitoring, and supervision of Low Voltage Power & Distribution, Emergency Power Supply-DG sets and UPS, Fire Alarm System, Hydraulic System (Bore Well Pumps etc.), and other nominated Building Services Systems. The ITCS shall also interface with the requirements for control, monitoring, and supervision as required at the Tunnel Control Centre (TCC).

The ITCS is to be designed manufactured, supplied, installed, tested and commissioned by the Concessionaire and

shall meet all performance and functional requirements as defined in the Specification. This specification contains a description of the system concepts and major components, and sections covering definitions, requirements for interfaces with other contracts, general mechanical and electrical installation design/performance requirements, and testing requirements.

The emphasis is to explain the requirements of work, interfaces with other Concessionaires for achieving an efficient & safe working system commensurate to the best international standards and practices. Every effort has been made to cite the design requirements very clearly, however in this contract, the Concessionaire shall follow acceptable standards & design procedures akin to the best adopted practices in ITCS system, wherever this is not explicitly mentioned.

## 2. Scope

The services to be performed by the Concessionaire shall include, but not be limited to, the following:

i Design, development, manufacture, verification, delivery, installation, testing, commissioning (including integrated testing and commissioning) and technical support for a complete ITCS , including all PLC/RTU Equipment, CPU's, Modules, Sub Modules, Power Supplies, Local Control Panels, PC Work Stations, Printers, Local Area Network (LAN), Ethernet Hubs and Switches, Remote Fireman's Control Panel, electrical containment and wiring systems, and other components, to fully integrate the control, monitoring, and supervision of Low Voltage Power & Distribution including Energy Metering, remote relay setting of ACBs, Diesel Generator System and strategic emergency power supply from DG sets, UPS, Lighting Control System, Fire Alarm System, Lift and Escalators, Hydraulic System (Raw Water pumps, Domestic water pumps and Fire Water pumps etc.) and other nominated Building Services Systems , as required whether or not specified , necessary to deliver the requirements of this Specification. The scope has been further given in detail as per I/O list with this document. The ITCS shall also interface with the requirements for control, monitoring, and supervision, as required at the Tunnel Operational Control Centre (TOCC). The system should be capable of independent functioning as well as seamless integration with centralized ITCS system.

ii Earthing of Programmable logic controller and Work Stations to the clean earth. Earthing drawing will be submitted to the employer’s representatives for approval.

iii Integration of ITCS with other ITCS at TCC.

iv Presentations, reviews and audit support as specified in the Specification;

v Interface management as specified in the Specification;




vi System operations and maintenance support services;

vii Training for the Employer's Engineers and Training Instructors, operations staff, maintenance staff and Engineering staff;

viii Dismantling, removal and/or disposal of Temporary Works;

ix Warranty period after commissioning.

x Transfer of Technology

xi Warranty and Maintenance Support System-AMC

The list is not intended to be complete and the Concessionaire shall supplement it adequately for obtaining a satisfactory working ITCS System.

**3. Standardization**

i The Concessionaire shall, in establishing his design, follow the principles provided below in the design and specification of all plant, equipment and components:

ii Similar plant and equipment shall be replaceable/interchangeable, modular in design, adaptable and extendable.

iii The technical specifications and design standards shall be uniform. Uniform standards for clear spaces, working clearances, protection of equipment and physical dimensions of equipment and interfacing with other systems.

iv Test standards and standardized equipment shall be selected or built or framed carefully, bench marked, designated and explicitly marked.

v A standard procedure shall be followed for identification of each category of equipment explicitly (suffixing or prefixing while marking and numbering for each category of equipment).

vi The operating system shall be uniform for all systems/sub systems.

vii Standards for maintenance planning shall be uniformly categorized.

viii Uniform standards shall be designated for procurement, replacement stocking and availability.

ix Equipment and accessories shall be provided with uniform standard spare capacity, protection.

x Piping, cabling etc. shall be suitably colour coded for identification and categorization for each kind of use/type. The cable terminations should be tagged and numbered as per the standards.

**4. Quality control of equipment, components and material**

The Concessionaire shall furnish the following information for each item of equipment as applicable:

i. Manufacturer.

ii. Type and model No. of equipment.

iii. Nominal capacity

iv. Power supplies i.e. Voltage & Frequency at which the equipment operates.

v. Type of Frame and foundation required for the equipment.

vi. Space requirements

vii. Controls & Protection

viii. Indications/alarm/annunciation

ix. Standards

x. Insulation class

xi. EMC Conformance and certification.

xii. Any other technical information related to the equipment.

The Concessionaire shall provide a list of tools and test equipment for the installation, testing and repair of any special apparatus and proposals for conducting system acceptance testing and to support the extended period of trial running.

**5. Submission of Drawing & Details**

i.The Concessionaire shall state the number and scales of all the drawings it intends to produce in support of the works under this contract. The detailed/schematic drawings to be furnished by the Concessionaire may include but not be limited to:

ii. Schematic drawings

iii. Interlock drawings

iv. Erection drawings

v. Wiring drawings

vi. As erected/finished drawings

vii. Any other drawings

viii. I/O Schedule and Cable Schedule

ix. A complete schedule of drawings to be produced by the Concessionaire shall be submitted to the Employers representative within one month (30 days), of contract award.

**6. Design Considerations**

a. The complete installation shall be in strict accordance with the national and local electrical codes.

i. All system components are to be designed and built to be fault tolerant:

ii. Satisfactory operation without damage at 110% and 85% of rated voltage and at +3 hertz & - 1.5 Hz variation in line frequency.

iii. Static, transient, and short circuit protection on all inputs and outputs.

iv. Communication lines protected against in-correct wiring, static transients and induced magnetic interference.

v. Bus connected devices to be a.c. coupled or equivalent, so that any single device failure will not disrupt or halt bus communication.

b. All equipment, cables and wiring shall be designed, manufactured and installed so as to secure a service life as shown below:

| | |
|---|---|
| Control Panels | 30 Years |
| Cables | 30 Years |
| Tray, trunking and supports | 30 Years |
| Sub-assemblies and components | 30 Years |
| All other equipment | 20 Years minimum |

c. Switchboards, equipment, and other control components shall be rated for operation in ambient temperatures of 15 deg to 35°C and humidity up to 55 to 85% and shall have degree of protection IP- 65.

d. In the design of switchboards, local control panels, Cabinets of PLC, an allowance of 20-25% spare space capacity shall be provided for possible future expansion and all panels shall be user friendly, modular and aesthetic design, termite and vermin proof. Spare capacity of 30% shall be provided for all cable trays, trunking, wire ways, (raceways), and brackets, for future expansion.

e. Parameters for control and monitoring for the various equipment location

| Functions | PLC (Plant Room) | | TCR | | TCC |
|---|---|---|---|---|---|
| | Condition | operation | Status | Alarm | Remote Data |
| Tube well pumps at station | Liquid level in the underground tank low. | Start Pump | Low water level in underground tank | Warning goes OFF when underground tank full | Warning |

| | | | | | | |
|---|---|---|---|---|---|---|
| (1+1) – MainStand+ by | Manual Switch remote | Bypass localor | Log at PLC | Red Graphics for local, grey for remote | | |
| | Pump Running | | - | Pump | | |
| | Pump Failure | | - | ON (OFF) | Standby pump fail warning | Warning |
| | Water level in the underground tank | | If full stop Pumping Log at PLC | - | - | - |
| | A defined time of pumping completed | | Alternating pump starts | Standby Pump is ON | | |
| | Hours of operation | | Log at PLC | - | Not run for more than a week, A Pump running for more than a defined time (Alarm) | Warning (Not Run for more than one week) |
| | Voltage | | Log at PLC | - | No Warning Volt | - |
| | Pump Tripped | | Log at PLC | | warning | Warning |
| Raw water pumps at station | Liquid level in the raw water tank low | | | Low water level in underground tank (Raw) | Warning, goes OFF when underground tank (Raw water) full | Warning |

| Functions | PLC (Plant Room) | | TCR | | TCC |
|---|---|---|---|---|---|
| | Condition | operation | Status | Alarm | Remote Data |
| (1+1) – Main + Standb y | Maual Bypass local or Switch remote | | Red Graphics forlocal,grey for remote | - | - |
| | Pump Running | - | Pump | | |
| | Pump Failure | - | ON (OFF) | Standby pump fail warning | Warning |
| | Water level in the Underground tank | If full stop Pumping Log at PLC | - | - | - |

| | | | | | |
|---|---|---|---|---|---|
| | A defined time of pumping completed | Alternating pump starts | Standby Pump is ON | | |
| | Hours of operation | Log at PLC | - | Not run for more than a week, A Pump running for more than a defined time (Alarm) | Warning (Not Run for more than one week) |
| | Voltage | Log at PLC | - | No Volt Warnin g | - |
| | Pump Tripped | Log at PLC | | warning | Warning |
| Domestic water pumps at station | Liquid level in the Domestic water tank low | Start pump | Low water Level in Domestic water tank | Warning, goes OFF when underground tank (Raw water) full | - |
| (1+1) – Main + Standb y | Maual Bypass local or Switch remote | Log at PLC | Red Graphics f local, grey for remote | - | - |
| | Pump Running | - | Pump | | |
| | Pump Failure | - | ON (OFF) | Standby pump fail warning | Warning |
| | Water level in the Domestic water tank | If full stop Pumping Log at PLC | - | - | - |
| | A defined time of pumping completed | Alternating pump starts | Standby Pump is ON | | |
| | Hours of operation | Log at PLC | - | Not run for more than a week,A Pump running for more than a defined time (Alarm) | Warning (Not Run for more than one week) |
| | PLC (Plant Room) | | TCR | | TCC |

| Functions | Condition | operation | Status | Alarm | Remote Data |
|---|---|---|---|---|---|
| | Voltage | Log at PLC | - | No Volt Warning | - |
| | Pump Tripped | Log at PLC | | warning | Warning |
| Fire Fighting Pump | Hydrant Pressure fall (Major) | Start the Pump | - | warning | warning |
| (1+1) Main + Standb y | | | - | | |
| | Manual bypass local or auto | | Different graphics colour for local or auto | - | - |
| | Pump Running | - | Pump 1/2 ON (OFF) | - | - |
| | Pump Failure | Start standby automatically | | First Pump fail warning | Warning |
| | Standby pump fail | Main pump starts automatical ly | - | Second pump fail alarm | Alarm |
| | A defined time of pumping completed | Alternating pump starts | Standby Pump is ON | | |
| | Hours operation of | Log at PLC | - | Not run for more than a week. | Warning |
| Jockey Pump | Hydrant Pressure fall (Minor) | Start the Pump | - | Warning | - |
| | Manual bypass local or auto | | Different graphics colour for local or auto | - | - |
| | Pump Running | - | Pump ON (OFF) | - | |
| | Pump Failure | - | | pump fail | Warning |

| | | | | | |
|---|---|---|---|---|---|
| | | | | warning | |
| | Hours operation of | Log at PLC | - | Not run for more than a week, (Alarm) | Warning |
| DG set | Incoming HT supply to Grid 1 & 2 transformers OFF | Bus Couplers OFF, start DG set, load breaker ON | Starting the DG set | Warning supply failed | Warning |
| | Start command from control panel | Start DG set, load | | - | - |
| Functions | PLC (Plant Room) | | TCR | | TCC |
| | Condition | operation | Status | Alarm | Remote Data |
| | Start command from local or remote | Breaker OFF | | - | - |
| | DG set running | | ON(OFF) | | |
| | Incoming HT supply to ASS transformers ON | DG set OFF Bus couplers ON | | - | - |
| | DG set failed to start or tripped | | | Alarm | Alarm |
| | Hours of operation | Log at PLC | DG set ON in casenot running more than 15 days | Not run for more than 15 days (Alarm) | Alarm |
| | Starter Battery Voltage | If low Log at PLC | | Warning, Maintenance required | Warning |
| | Lube oil Level | Continuous monitoring | | | |
| | Fuel level | Continuous monitoring | | | |
| | Radiator water level | If low Log at PLC | | | |
| | Output voltage | Log at PLC | Within range, | Alarm, if out of | Out of range |

| | | | | | |
|---|---|---|---|---|---|
| | Output Frequency | Log at PLC | Indicateon Load | range | alarm |
| | Fuel Consumption | Log at PLC | Weekly report generation for fuel consumption rate vs. energy output | - | Weekly report generation for fuel consumption rate vs. energy output |
| | Energy Output | Log at PLC | Continuous monitoring | - | Continuous monitoring |
| UPS(Electrical) | | | | | |
| | Input Voltage | - | Continuous monitoring in decimal value | | |
| | Battery Voltage | | Continuous monitoring in decimal value | | |
| | Charging Current | | Continuous monitoring in decimal value | | |
| Functions | PLC (Plant Room) | | TCR | | TCC |
| | Condition | operation | Status | Alarm | Remote Data |
| | Output Voltage | | Continuous monitoring in decimal value | | |
| | Output Frequency | | Continuous monitoring in decimal value | | |
| | Load% | | Continuous monitoring in decimal value | | |

| | | | | | |
|---|---|---|---|---|---|
| | Static bypass/ manual Maintenance Bypass | | Different graphics Status for Various status | | |
| | Mains failure | | Alarm | | |
| | Low battery Alarm | | Alarm | | |
| | Overload and over temperature | | Alarm | | |
| Battery Charger (ESR) | | | | | |
| | Input Voltage | Log at PLC | Continuous monitoring in decimal value | | |
| | Battery Voltage | Log at PLC | Continuous monitoring in decimal value | | |
| | Charging Current | Log at PLC | Continuous monitoring in decimal value | | |
| | Output Voltage | Log at PLC | Continuous monitoring in decimal value | | |
| | Mains failure | | Alarm | | |
| | Low battery Alarm | | Alarm | | |
| | Overload and over temperature | | Alarm | | |
| Functions | PLC (Plant Room) | | TCR | | TCC |
| | Condition | operation | Status | Alarm | Remote Data |
| | Charging/Load/B oost Charging Status | | Different graphics Status for Various status | | |

| | | | | | |
|---|---|---|---|---|---|
| | Static bypass/ manual Maintenance Bypass | | Different graphics Status for Various status | | |
| Entry/ Exit/ Forecourt, External (Road) Lighting | Voltage | - | ON (OFF) in defined time period | No volt Alarm | Alarm |
| | Current | If less than 80% of nominal value in any circuit | | Lamp replacements due | |
| | Hours of operation | Log at PLC | - | - | - |
| | Energy Consumption | Log at PLC | Decimal Value | - | Decimal Value |
| Fire Detection and Alarm System | | | | | |
| All zones Public Areas | Alarm Situation | Signal at FACP | - | Warning | Warning |
| All zones Non- Public Areas | Alarm Situation | Signal at FACP | | Warning | Warning |
| All zones Non-Electrical Installatio ns | Alarm Situation | - | Gas Release monitoring | Warning | Warning of fire at zones and gas release |
| All zones Non-Hazardous Areas | Alarm Situation | Signal at FACP | - | Warning | Warning |
| FACP | System Fault | Fault Indication | ON | Warning | Warning |
| | External Fault | Fault Indication | ON | Warning | Warning |
| | Processor fault | Fault | ON | Warning | Warning |

| | | | | | |
|---|---|---|---|---|---|
| | | Indication | | | |
| Functions | PLC (Plant Room) | | TCR | | TCC |
| | Condition | operation | Status | Alarm | Remote Data |
| | Device fault/ Device isolated | Fault Indication | | Warning at fixed interval | Warning |
| | Voltage | Log at LDC | | No volt warning | - |
| Sprinkler | Rise in Temperature | Start Pump | ON | Warning | Warning |
| Hydrant | Low pressure | Start Pump | ON | Warning | |
| Electrical Panels | | | | | |
| | Manual bypass local or auto | | Different graphics Colour or auto | | |
| | DB running | - | DB ON(OFF) | Warning for No volt in EPP | Warning |
| | Energy Consumption | Log at PLC | Continuous monitoring in decimal value | - | Continuous monitoring in decimal value |
| | Voltage | Log at PLC | | No volt alarm | |
| | Trip | Log at PLC | Red colour in graphics | Alarm | |
| | Communication and setting of ACB Relays | Log at PLC | | No volt alarm | Control and setting of ACB relays |
| | Control Supply failure | Log at PLC | | No volt alarm | |
| Lighting system | | | | | |
| | Manualbypass local or auto | | Different graphics colour for | - | - |

| | | | | | |
|---|---|---|---|---|---|
| | | | local or auto | | |
| | Light Circuit ON/OFF Command | - | Light ON (OFF) | - | |
| | Light Circuit Failure | - | | Circuit fail warning | Warning |
| | Light Circuit ON/OFF Status | - | Light ON (OFF) | No 'ON' status alarm | Warning |

The workstation pc with recent configuration and operating system shall be supplied andinstalled in the station control room of each station. This shall be a standalone PC.

**7. Programmable Logic Controller (PLC)**

a. Necessary PLCs shall be installed to provide the most economic configuration based upon cost balances between PLC modularity and cabling costs, consistent with the performance requirements of this specification.

b. Location of PLCs shall be chosen such that minimum length of cable will be required between PLC and power DB.

c. PLC can be opened freely, so sufficient distance from the wall or obstruction will be maintained.

d. Cables shall be kept at a distance of 300 mm from the power cable trays/conduits at all places as entry/exit to DB, PLC etc.

e. Hubs / switches — these will be installed in separate enclosures near the, PLCs/ workstation.

f. Repeaters- these will be installed in separate enclosure at a distance of 90 meter from hub/ repeater of the communication cable to boost the signal.

g. Field sensors- sensors will be located on, or adjacent to, that equipment which is being monitored. For example, it could include sensing the electrical load, water level etc. that changes within building.

**8. Facility**

a. The ITCS system shall be centralized and comprise of a powerful central computer. This shall run highly sophisticated programs, which operate in 'real-time'. Workstation shall have continuous communication between the central or main operator station's central processing unit (CPU) and the remote field processing units (PLCs). The CPU is continuously updated with the conditions being monitored by, and control actions being taken by, the PLCs. It will therefore be able to implement global actions with the minimum time delay, across the whole system. However, configuration of PC and hardware components given in subsequent paras of this specification.

b. A central database management and communications system, to communicate with the PLCs and local workstations over the communications link shall be provided and to maintain a database regarding health and operation of all system points. The system should be able to log the defective sub-systems, communication failures/ breaks and also update the data on restoration of the fault.

c. Bulk data server facilities for software back up and historical data, including equipment history of maintenance & frequent defects shall be provided at Tunnel & T.C.C. Maintain equipment history of maintenance and frequent defects. The backuphistorical data shall be available minimum for a month at a time and backup rate shall be fortnightly.

d. The ITCS should activate designated alert for the attention of operations and maintenance Tunnel passengers (for example lighting system, escalators). SMS to Mobile phones of DGM (O&M) and other designated officials of employer regarding high priority alarms, energy audit reports and specific fuel consumption of DG sets.

e. Provide clear, comprehensive displays and printed logs of equipment status to each operator workstation.

f. Provide comprehensive displays and printed logs based upon historical data, with the option of overlaying data from earlier periods.

g. Time-tag all events detected by the ITCS system, to 1 millisecond Resolution for selected high-speed inputs, and to present this information in logs as a true system- wide sequence of events.

h. Generate routine maintenance schedules automatically, based upon elapsed time and equipment operation times. Also record the maintenance activities carried out including the maintenance block taken, persons attending or having access to the plant rooms.

i. Operating systems based on a Graphical User (GUI) format incorporating the widely used WIMPs procedures (windows, icons, menus, and pointing device), where one display can overlay another shall be provided. WYSIWYG (what-you-see-is-what- you-get) display printing and print previewing features shall be provided.

The following primary facilities shall be available at each workstation:

i. Visual and Audible Alarms and event logging and printing.

ii. Operator acknowledgement of alarms.

iii. Selective display and printing of alarms and of events lists.

iv. User friendly group display on a single Screen of various E&M systems.

v. Execution of operator commands with access code security.

vi. Provision of user-friendly operator sequences.

vii. Operator entered text messages.

viii. Access to historical data files of plant status.

ix. Generation of tabular displays based upon spreadsheets.

x. Generation of graphical displays based upon mimic diagrams.

xi. Generation of printed reports and printed copies of display pages.

xii. Utilities consumption monitoring and check metering.

xiii. Operator entered data, including tagging, manually entering values and the forcing of status points.

xiv. Automatic logging of selected displays at specified times.

xv. System timekeeping.

**9. Specification/requirements for hardware components**

The requirements and specifications for hardware components of the PLC is as follows:

**a. Components of PLC**

i. PLC consists of main CPU, I/O modules, DC/DC converter and terminal blocks. It collects data from the process, pre-processes and transmits the same, using suitable protocol (MODBUS RTU or similar), to the TCR Workstation which in turn communicates to the Central Server at the TCC via an optimized and event-based TCP/IP protocol.

ii. PLC shall be an intelligent modular, compact system that allows suitable expansion, minimum from 14 up to 1000 I/Os using the same set of basic components. The PLC shall be programmed for local control by implementing specific logic in the PLC. Input and Output modules are connected serially to make it a complete compact and modular data acquisition system. The PLC shall communicate with TCR workstation through MODBUS Protocol, using the RS232/485 port. PLC shall have a local 'intelligence' so that in the event of a breakdown in communications with the CPU, the points connected to that unit continue to be controlled according to the time schedules initially provided by the CPU.

iii. The Concessionaire shall ensure that the PLCs are compatible with the input/output signals from the Workstation and other Subsystems. Power supplies for interrogation of volt-free contract shall be provided as part of the PLC.

iv. PLC terminals shall be of the clamp type preferably of cage -clamp and shall be provided with isolating links

v. PLCs shall be supplied complete with 30% spare capacity for handling additional input and output signals. Expansion by at least 50% shall be possible simply by adding more I/O modules and reconfiguring the software. A further 100%

expansion shall be possible by adding additional interfacing equipment in additional cabinets, etc. and reconfiguration of the software.

vi. A manual switch inside the PLC cabinet shall be provided as a hardwired facility to disable the operation of control outputs. Change of switch status shall be registered as a system event.

vii. The Concessionaire shall establish the I/O requirements and provide the most economic configuration of PLCs based upon cost balances between unit modularity and cabling costs for individual stations.

viii. The PLCs shall be suitable for either wall or floor mounting and shall be suitably robust for operation in Electrical switchgear room/ Pump room areas, to IEC529 IP54 enclosure standard Wall mounting is preferred. PLC shall be of the same make and type at all sites and individual components shall be interchangeable between PLCs at different sites.

ix. The PLCs shall be suitable for operating in the environment described in the General Specification clause.

x. The PLCs shall be able to be interrogated fully and be fully reconfigured from operator workstations. The Employer's personnel shall be able to re- configure fully the PLC hardware and software after completion of the training courses provided under this Contract. However, a nominated person with authorized password should have access for making such change with using proper authorization from DGM/ TUNNEL or TCC, EMPLOYER.

xi. It shall be possible to disable an individual PLC locally or from an operator workstation for servicing or reconfiguring without affecting other PLCs. When disabled or enabled, a change of status condition shall be announced on the Control Center monitor and the changed log as an event.

xii. Internal architecture of PLC

- Microprocessor base CPU
- Input and output interface modules suitable for a mixture of digital, analog and pulse inputs and outputs.
- Terminal for external cable termination
- Thermostat for temperature control
- Power indication lamps
- Document holder
- MCBs for modules, Fan, Tube lights
- Door switches
- Fuses for digital output, input and analogue input terminals
- Power supply unit

xiii. The PLC processor will have minimum Salient features as following:

- 34 KB user program memory RAMS and Flash.
- 0.4 ms/kobo bit processing
- Integrated ports: 2xMODBUS or 1xMODBUS.
- interrupt inputs and 2 cyclic tasks.
- Direct access to I/O for fast response.
- Real-time clock.
- It shall have real time clock & time resolution of the clock should be lmsec.
- PLC shall have separate battery for the above clock. PLC shall be capable of time stamping the event before communication to ITCS.
- The event scanning resolution of PLC should be of 1msec.

xiv. The PLC processor will have the capability to support the following language structures:

- Structured Text
- Sequential Function Charts

- Ladder Logic
- Function Block

The processor shall support the Advanced Instruction Set that includes basic and advanced ASCII string instructions, and advanced math functions.

The processor shall support a system protection environment with passwords and privileges and support a form of backup communications module.

xv. PLC Interface Modules

The following hardware described will interface to the field mounted sensors and equipment for control and monitoring.

Digital inputs:

12 VDC, 24 VDC, 50 VDC, 110 VDC, 110 VAC, 240 VAC (1.5 kV isolation)

Digital Outputs (relay):

Volt-free contact, 24 VDC, 30 VA Volt-free contact, 240 VAC, 125VA Analog inputs:

0-10 VDC, 0-10 mA, 4 -20 mA with electrical isolation from ground DC 12-bit resolution minimum

>60dB interference rejection at 50Hz

Analog Outputs:

0-10 VDC, 4-20mA

Pulse Inputs:

12 VDC, 24 VDC up to 10 pulses/sec (2kV isolation)

Serial Link:

RS 485, RS 232 / V24, RS422

**b. PLC Hardware Requirements**

PLC Operating Voltages: The PLC must be able to operate at 100% from the following power sources:

100 VAC — 250 VAC

24 VDC — 100 VDC

Note: The PLC must operate at the nominal supply frequency of 50 Hz with a 15% variation.

**c. PLC Programming**

i. The PLC shall be programmed with manufacturer proprietary software, IEC 1131.3-compliant, mixable and reversible List language and Ladder language. The software shall feature Windows-based editing functions and integrated online help.

ii. An original copy of the latest manufacturer's proprietary software shall be provided to EMPLOYER upon completion and handover together with all generated site-specific data.

iii. PLC should be remote programmable from TCR workstation.

**d. PLC communications**

Although the PLC processor specified above will have the capability of communicating directly with an ITCS system via Modbus over TCP/1P protocol. In addition to the above, the PLC shall have the capability to be monitored directly using the HTTP protocol.

**I. PLC Cabinet and Panel Internal Wiring**

i. PLC is compact and modular in design. All the components inside the panel are din-rail mounted. PLC cabinets will be freestanding type and will have colour matching with Electrical Panel.

ii. Control panel, switchboards and distribution boards wiring shall be clearly identified in accordance with the Definitive Design Drawings using cable core markers. Cable core markers shall read left to right or top to bottom.

iii. Wiring shall be enclosed in metal ducts or neatly loomed with nylon ties or spiral binding as required. Wiring ducts shall be filled to a maximum space factor of 50%.

iv. Where wiring is required to connect to devices mounted on doors it shall be arranged such that opening and closing of the door is not impeded whilst minimizing flexing of the wiring loom. The loom shall be effectively fixed at both ends of the door opening with insulated saddles or clamps.

v. Wire colours shall comply with the following requirements: Phase Red, Yellow, Blue

Neutral Black

AC Control Grey

DC Positive Orange

DC Negative Lilac

Earth Green with Yellow trace

vi. Terminals shall be clearly numbered, and shall be rail mounted, adequately sized to suite wiring size and provided with 20% spare rail space. The bridging of terminals shall be provided by the use of terminal bridging links as supplied by the terminal manufacturer.

vii. Control wiring shall be terminated using pre-insulated pin or spade type crimp lugs. Conductors terminating to study type terminals shall be fitted with spade type crimp lugs.

viii. A separate earth bar shall be provided for the termination of all earth wires. Only one wire shall be connected into each termination point.

ix. Minimum conductor size shall be 1.5mm2.

x. Cable glanding plates shall be earthed directly to the control panel earth bar.

xi. Panels shall be fitted with a suitable pocket to contain circuit diagrams and other relevant Definitive Design Drawings. An "as installed" set shall be provided with the panel.

**II. ITCS MAIN Server**

SCADA Server shall be provided with minimum following requirement:

i. Processor - 3.2 GHZ Intel Xeon 64 Bit Processor (Latest series available) with heat sinks

ii. RAM size – DDR3/DDR4 based 2X16GB

iii. 4 GB dedicated graphics card.

iv. Hard disk- Total storage of 3TB each, with RAID-6 or suitable hard disk controller.

v. Visual Display Unit- 19-inch rack integrated LED or equivalent.

vi. Video Card- Standard Graphics controller.

vii. Multimedia with accessory- Not required.

viii. DVD R/W- Dual Drives: 16x DVD-ROM Drive + 16 x DVD+/-RW double layer write capability.

ix. EMI immunity- As per IEC 801.

x. Inbuilt Network Interface Ethernet Ports

xi. Built in dual gigabit port, Ethernet GB Lan Card

xii. USB ports- 3.0 USB (4 Nos)

xiii. Server Management software- Complete with the server management software & Tool for server diagnostics and troubleshooting, including other drivers for the server.

xiv. Accessories- Accessories Including all cables/ connectors/ Keyboard/ accessories to achieve the complete working of the system.

xv. Power Supply-Fully Redundant Power Supply & Fan Unit

xvi. Operating System- Microsoft Window server Windows server 2016/ Windows server 2019 or latest windows server

xvii. External Hard Disc- Not Required

xviii. Tape Drive – For backup Required

**III. Personal Computer**

i. The Standalone commercial grade Work Station shall be a personal computer (PC) based central, with a minimum feature of full 32 bit processor, features latest Intel I7 , 5th Gen processor with 3.0 GHz or higher, 8 GB RAM, 1TB Hard Disk drive, ATI/NVIDIA graphics card , DVD R/RW, Dual LAN card, 2GB Dual Video Accelerator, Dual Monitor support, 2 Nos. spare USB ports, SATA/SCASI disk drive crashworthiness, and all other miscellaneous components including communication interface RS-232/485 card (MOXA Card with minimum 8 ports) to meet the requirements and specifications. Notwithstanding the foregoing guidelines, the Work Station shall be to the latest state-of-the-art performance for similar systems and shall be operated by the use of a USB mouse (Optical) connected to the station without the need of keyboard entry. To ensure hardware quality, computer clones shall not be acceptable. The PC shall be supplied with 24" VDU, One Laser Printer and with latest operating system software.

ii. The PC shall be configured such that external media of any kind may not be loadable at Operator level, which could pose the threat of external virus infection or compromise the operating system.

iii. The Work Station shall be complete with detached 101-keys keyboard, which includes full upper/lower case ASCII keyset, a numeric keypad, dedicated cursor control keypad, and a minimum of 30 programmable function keys.

**IV. Colour Monitor**

The Work Station color monitor shall be Colour monitor shall be minimum 22- inch diagonal antiglare, antistatic flat LED screen, high resolution of 1280x1024 and 16 Million colour support, on screen control support, Vertical & Horizonal viewing angle 160O, Tilt Swivel Support as per specifications etc. as required Work stations shall include all accessories needed to comply with UL requirements for listing under the appropriate standards as specified in UL864 and UL916.Further, all accessories shall be included to satisfy the local authorities having jurisdiction over the system. UL listed cards (originals preferred or photocopies) shall be provided to support the documentation that such listing is in effect.

**V. Printers**

The sub-Concessionaire shall provide printers as specified for recording alarms, operator transactions and system reports. To ensure hardware quality, printers shall be internationally branded, warranted, and technical support, spare parts and consumables should be freely available from the manufacturers authorized distributors.

**VI. Laser Printer**

A hard-copy multi-color graphics laser printer shall be provided for recording graphic displays and associated dynamic data. Printer shall meet minimum requirements as follows:

i. Print speed — Black: up to 20 ppm; color: up to 4 ppm

ii. First page out — 18 seconds black, 29 seconds color

iii. Resolution- 600 by 600 dpi

iv. Memory — 64 MB built-in SDRAM; expandable to 192 MB with one open memory SDRAM DIMM slot

v. Duty cycle — 30,000 pages per month

vi. Media — Media handling 125-sheet multipurpose tray 125-sheet multipurpose tray, 250-sheet input tray 2 — Letter, legal, statement, executive, No. 10 envelopes, Monarch envelopes

vii. Output — 125 sheet face down bin

viii. Types Paper (plain, letterhead, prepunched, bond, color, rough, preprinted, recycled)

ix. Glossy Media, Cover Paper, Color LaserJet Transparencies, labels, envelopes, and card stock

x. Compatibility - Interfaces Hi-Speed USB 2.0 port, IEEE 1284-B compliant parallel port

xi. Hi-Speed USB 2.0, IEEE 1284-B compliant parallel port

xii. Languages PCL 6 and Postscript level 3 emulation with automatic language switching

xiii. Font capabilities — 80 TrueType TM internal scalable PCL 6 fonts; 80 TrueType internal scalable HP postscript fonts

xiv. Client operating systems — Microsoft Windows 98, 2000, Me, XP, NT 4.0 Mac OS 9.1, X v.10.1 and later; UNIX®, Linux, and OS/2 (limited functionality) vista, Windows 7, Windows 10.

xv. Network operating systems — Microsoft Windows 98, 2000, NT 4.0 Me, XP; Mac OS 9.x, OS X Vista, Windows 7, Windows 10.

xvi. Network protocols supported — TCP/IP

**VII. Network Switches, Modems, Hubs, Gateways**

All modems, hubs, switches, gateways and other serial equipment to be used in the application of system networks must be of industrial grade quality to meet the following criteria:

i. Can tolerate up to -40 to 85 deg C

ii. Can tolerate 5-95% humidity

iii. Provides vibration resistance (1E68-2)

iv. Withstands power surges (IEEE-472)

v. Provide easy DIN-rail mounting

vi. Are powered directly from 230V AC/110V DC

vii. Not less than 8-port 10/100 Dual-Speed ports-up to 200Mbps

**VIII. Communication**

The suitable communication protocol shall be adopted for various communication links. The communication Protocol can be classified as per following requirements:

i. The communication between E&M equipment to PLC: MODBUS Protocol

ii. The communication between PLC to the TCR Workstation: MODBUS Protocol over TCP/IP.

iii. The communication between Multifunction Meters and Energy meters and their communication to PLC/Workstation: MODBUS Protocol on RS 232/485 port.

iv. The communication between Dimming Light Control Panel, Fire Alarm Control Panel, and MDB & Electrical panels, Escalator Panels/MCCBs, AMF Panel etc. to the PLC/TCR Workstation: MODBUS Protocol on RS232/485 Port.

v. Communication between TCR Workstation to TCC: TCP/IP protocol on optic fiber link through TER.

vi. Supply of the hardware essential to integrate all systems for communication link as above.

vii. The communication link between TCR workstations and the TCC shall be done using TCP/IP based protocol. All the TCR workstations and TCC shall be connected in LAN TCP/1P that is being provided at TER by the main communication Concessionaire.

viii. Communication software in each PLC or workstation node on the network shall enable peer-to-peer operation, such that failure of any node shall not affect other nodes on the network.

ix. The system should provide instant alarm to the operator about the communication failure.

x. The healthy operation of all PLCs shall be verified at intervals not exceeding 30 seconds. PLC failure shall be displayed on the appropriate workstations as a system alarm.

xi. In the event of a failure of the main communications system, local operation from control panel at each station shall be maintained. Updating of the central database at the TCC shall take place immediately on restoration of the communications link.

xii. Operational changes and expansion will be made without shutdown the system.

xiii. Cables

**10. All types of cables used in this project shall be Armoured**.

i. Cables installed between PLC and DB/Sensors shall be Fire resistant low smoke Zero Halogen (FRLSZH)

ii. Cables installed between PLC and DB/Sensors shall be not less than 1.5 sq mm copper.

iii. Ethernet cables for networking of PLCs and Workstation shall be provided.

iv. 2#3C shielded cables (communication bus) shall be provided over RS232/485.

**I. Moxa card/ Router**

a. For communication with RS 485 port of different panels Moxa card of minimum 8 ports/Router shall be installed with the ITCS workstation.

b. Cables installed between PLC and DB/Sensors shall be not less than 1.5 sq. mm copper.

## 11. Specification/Requirement for System Software

### I.Software features

a) It is necessary to provide a time and date for alarms, which occur, and other significant events, including operator commands.

b) Software will allow the database (points) and operating parameters (time, temperatures, limits etc.) to be modified on-line, by the operator.

c) When a binary contact goes from open to closed, or vice versa, the 'change of state' is reported by the system.

d) Some alarms may, however, be critical and should never be locked out. It should be possible to define these alarms when they are entered into the system in such a way that it is impossible to lock them out.

e) On start-up of certain plant, it takes a finite time before stable conditions are reached and the ITCS should allow for automatic lockout of alarms for a pre-set period following start-up.

f) If, either as a result of time programming, or an operator command, several large electrical items are called to start at the same instant, this may cause overloading. ITCS shall have capability to overcome this by defining these items as 'heavy' electrical items, and introduce a delay time to prevent starting of the next load until delay time has elapsed.

g) Logging of important status information will be provided. The list of such important items shall be provided by Concessionaire for approval of ER.

h) This should contain, in plain language, identification of the point, status and other data, plus time, date etc.

i) It should be possible to call up logs for various 'levels'.

j) It should be possible to cancel logs under certain conditions.

k) Facility of summary logs, i.e. the ability to call for a print out, for example, of all points in alarm, all points off normal, all motors which are running, all points which are locked out, etc.

l) It should be possible to log system advisory messages, e.g. malfunctions within the management system itself, such as hardware failures, power loss, failure of a point to respond to a command, communication errors etc.

m) Operator will be allowed to define the engineering units, e.g. voltage, kWh, degrees centigrade, etc., and the ranges over which they are to be measured.

n) An alarm should be reported in case of breaking the pre-set limit of analogue points such as voltage, current etc.

o) To avoid nuisance alarm, the software should have flexibility to allow varying the differentials or introducing time lag. For example, if a space temperature alarms at 25°C high and has a 0.1°C differential, it will be constantly going in and out of alarm between 25°C and 24.9°C. It would probably just as acceptable to have a 2°C differential which would reduce the number of alarms reported considerably and furthermore, when they did occur, would be more meaningful to the operator.

p) It should be possible to lock out analogue alarms, both by the operator and automatically, during start-up maintenance operations if nuisance alarms are to be avoided.

q) It should allow start/stop commands to be set up at precise times, with daily variations as well as allowing holiday programming.

r) The system will keep a record of how many hours a plant has been running or how long a point has been running or how long a point has been in a normal or off-normal condition.

s) Limits to be set which can be used to alert the operator to the fact that maintenance is necessary or perhaps can automatically switch from one pump to another after a present period.

t) A record of consumption of things such as litters of fuel used, kWh etc. will be kept.

u) English language for both input and output will be accepted.

v) The output information should be grouped in accordance with the make-up of the `services' systems in the station building rather than the location of the field hardware.

w) "Prompting' feature will be provided, which takes the operator through the operation step by step, prompting and teaching him as he does it.

x) Dynamic colour graphics will be used to show the schematic diagram of the system.

y) Different colours will be used to bring particular conditions to the attention of the operator. The Concessionaire should submit scheme in this regard for approval of Employer's representative.

z) The operator will have the facility to generate or draw his own graphics on the VDU and have a library of standard symbols available to him held in the memory of the system.

aa) Password will restrict access to certain important areas, so it is necessary to control who has access to a ITCS, at what level and through which operator devices.

bb) Number of characters of password will not be less than five. cc) Password time-out will be not more than half an hour.

cc) "Database save' feature to copy the system database onto a separate storage medium, usually a disk, will be provided.

dd) Equipment's will run on its requirement; in the rest time it will be possible to be switched off to save the energy.

ee) HMI software- On the front Screen icons for all systems shall be shown. Healthy and unhealthy status of these systems shall be shown by dynamic colour change of these icons.

**II.General**

a) The PLC shall be application-software controlled, with the software assembled from proven software modules, and shall be capable of the following function and facilities:

i. Local time tagging of events.

ii. Alarm handling from discrete inputs derived parameters.

iii. Combining of digital inputs Boolean functions to give conditional outputs.

iv. The equipment shall be self-monitoring for fault conditions, and shall generate an alarm on the appropriate operator workstations in the event of a fault arising.

b) PLC- software shall be capable of being reconfigured, under password control, either locally from the portable-programming device to be supplied under the Contract, or remotely over the communications links from operator workstations.

c) Event processing shall have the following order of precedence, but shall be re-configurable:

i. Receipt of manual commands from operator workstations, each of which shall have an assignable level of command priority.

ii. Pre-defined control sequences.

iii. High-speed alarms.

iv. Normal alarms.

v. Digital events.

vi. Clock synchronization (With the master clock at TCC).

vii. Analogue events.

**III.Design and performance requirements**

Equipment or systems comprising several components shall be controlled through the ITCS with suitable control regimes to achieve desired operation normally automatically but with provision for manual intervention. The automatic operation shall conform to the operational, functional and overall system needs as specified in this specification.

**a.** The Concessionaire shall prepare in clear and logical form documents describing the functions transmitted and the operations carried out at the stations control room workstation and that at TCC. The control and transmission scheme shall be submitted for the consent of the Employer or his representatives.

**b.** The equipment shall also have arrangements to log and record various parameters on a regular basis and store the results for at least six months.

**c.** The ITCS supplier/ Concessionaire may propose the use of a serial data link instead of voltage free contacts. In this case the physical characteristics and data transmission protocol proposed shall conform to an internationally recognized publicly available standard. If there should be a match between the ITCS supplier's proposal and the capabilities of the electrical/mechanical equipment in the field for serial data link to be adopted with the consent of the Employer. The Concessionaire shall interface with other electrical and mechanical equipment supplier, as per the interface matrix.

## IV. Design Coordination Requirements

The Concessionaire shall submit a list of all design review documents for the review of the Employer's Representative.

## V. Applicable Design standards

- IEC – 1131
- IEC-6206
- IRC SP; 87-2013.
- IRC SP 91.

The above specifications shall be applied in a manner altered, amended or supplemented by this specification and the latest Indian Electricity rules wherever applicable.

## VI. Lightning

**a.** The Concessionaire shall ensure that all equipment's are fully protected against the effects of mains surges and direct and indirect lightning strikes. Protection such as high voltage cut outs or high current cut outs shall be applied to incoming mains power supplies and to input and output signal lines to externally located sensors, transducers, actuating equipment, etc. or to any other equipment likely to be affected.

**b.** Lightning protection systems shall be in accordance with BS 6651 — "Lightning Protection" or an equivalent Indian/international standard.

**c.** All surge suppression equipment shall be self-contained and self-resetting.

## VII. Alarm

**a.** All alarms generated by the installation including processor alarms, power supply alarms, and control equipment alarms, shall be sustained until cleared. Alarm handling shall be implemented through the ITCS system.

**b.** Alarms will flash on the present Screen and be audible to the station controller; it will be messaged to the mobile phone of the station controller and other concerned EMPLOYER authorities, as decided by the Employer.

**c.** The Alarm shall be in a form of a hooter positioned at SCR, near to the ITCS system.

## VIII. Selection of equipment's

**a.** The Concessionaire should select the equipment's, subsystems of the ITCS keeping in view the requirements given in this specification.

**b.** In their technical bid, the bidders should provide details of systems, its subsystem, components etc.

## IX. Installation

**a.** It should be ensured that the noise within the communication links between the PLC and the TCR Workstation is avoided.

**b.** Proper installation techniques should be employed to ensure adequate quality of signals from analogue sensors (transducers) to PLCs.

**c.** Adequate measures shall be taken by the Concessionaire to mitigate potential problems confronted due to the various forms of interference.

**d.** A semi-rigid, shielded cabling, which is, to a certain extent, self- supporting, can be used for signal and communication wiring.

**e.** The Concessionaire shall supply and install all materials including but not limited to cable tray, brackets, and supports and execute all other works needed for supporting and routing all cabling and wiring relating to ITCS. The Concessionaire shall interface with Building/ Civil Concessionaires will make provisions in structures to accommodate the fastenings.

**f.** The PLCs should preferably be wall mounted. All floor mounted PLCs will be grouted in the floor, so that vibrations due to tunnel vehicle movement can be born. If the problem persists then rubber AVMs can be used.

**g.** Separate tray, trunking and conduits will be used by the Concessionaire for ITCS cabling.

**h.** All cables will be laid in tray, trunkings, and conduits as appropriate etc. Saddling of cables on the wall shall not be permitted.

**i.** Dressing of cables will be done in such a manner that all cables will be laid parallel without laying/ crossing on each other. All the cables shall be properly tagged and marked on both ends and along the cable.

**j.** Bunching of cables near PLC entry, Power feeder entry and anywhere not permitted.

**k.** All trays, trunkings and conduits will be marked with a definite colour and tray will be marked clearly as 'ITCS Control'.

**l.** A separate team of experienced ITCS installation engineer, Software engineer, Electrician, Unskilled persons etc. will be kept for ITCS work, for work completion as per schedule in the contract. A list of such team will be submitted to the Employer's representative one month before of the start of work.

**m.** Scaffold, welding machine, soldering iron and other tools/special tools &plants required for execution of works under this project shall be arranged by the Concessionaire.

**n.** Installation, testing schedule will be provided one month before start of work and weekly progress will be submitted to the Employer's representative.

**o.** Without complete installation, tray marking, cable tagging and dressing etc., no test will be allowed.

**p.** Where cables cross the track, wall or are in any part external to cable trough routes, then they shall be suitably protected through PVC conduits encased in concrete. Advantage shall be taken, in consultation with the Civil Concessionaires, to incorporate such additional protection into the basic construction of the concrete structures.

**q.** All cables except main power supply cables, entering or leaving equipment rooms and wayside apparatus boxes shall be terminated in order of their core number on combined terminal/disconnection or terminal/fuse links.

**r.** Each wire shall be capable of being disconnected and isolated without removing the wire itself. These links shall be easily accessible for inspection and test. Each link or terminal shall be identified with the designation of the circuit it carries.

**s.** All electronic equipment shall comply, as a minimum, with IEC 571 or equivalent international specification. All components used shall be purchased from suppliers complying with internationally recognized quality management and reliability certification procedures. The Concessionaire shall declare in his offer the specifications to which he proposes to comply.

**t.** Printed circuit boards shall be used to mount electronic components. The boards shall be of sufficient thickness to ensure mechanical rigidity. They shall not be the sole support for connectors, fascia panels, handles etc.

**u.** All components shall be identified either by carrying a manufacturer's designation or part reference number or unique value in a standard format.

**v.** All metal enclosures shall be provided with an earthing terminal. The Concessionaire shall ensure that all the equipment's are properly and adequately earthed in accordance with safety standards and its rules.

## X.Testing General Requirements

There will be five type of tests-

**a.** Factory Acceptance test for PLC, Workstation and Printer- During the test all logics shall be demonstrated with simulator and sample PLC, Workstation and printer.

**b.** Installation test- After delivery of the PLC at the site, this test shall be arranged to check the physical healthiness of the hardware.

**c.** Functional test- This test shall be arranged -to test the functioning of PLC, workstation and printer and communication network.

**d.** System acceptance test- This test shall be arranged to test all automation and 1/0 list, with integration of communication network.

**e.** Integrated test- This test shall be arranged to test the integration of the ITCS server at TCC and all workstations of different stations.

However, indicative S.A.T document shown in this specification, but it is Concessionaire's responsibility to submit the separate test document for each type of test to the approval of Employer's representative. All tests shall be in sequence and on completion of previous test, next test shall be arranged. Before installation test, all QA/QC document shall be submitted to the Employer's representative for the approval.

Basic monitoring and control functions will be demonstrated on a point-by- point basis. Checking out the software features is much more difficult and many of the programs will only be proved correct or otherwise by closely monitoring the ITCS operation over an extended time period. The Concessionaire shall provide necessary support till the time the system is reasonably established.

A re-commission or check out of the operation of the ITCS at the end of twelve months shall be carried out.

The following requirements are intended to supplement and explain the general specification requirements without in any way limiting their application.

**a.** The testing philosophy for the ITCS System shall ensure that the equipment functionality is thoroughly verified and validated at the Concessionaire's premises before delivery and commissioning. The test methodology shall be in line with the design methodology and the two shall be developed in parallel.

**b.** The principle of testing shall be that, at stages throughout the work, formal tests shall be performed and recorded against written test specifications, to provide a high level of confidence to the Concessionaire and the Employer's Representative that subsequent stages can proceed.

**c.** The responsibility for specifying, conducting and recording tests shall be with the Concessionaire, but all aspects must be to the satisfaction of the Employer's Representative. The Employer's Representative will at his discretion witness any tests. The degree to which the Employer's Representative intervenes in the process will depend upon the level of confidence built up during the project.

**d.** This document does not constitute a Test Specification or Test Procedure for any part of the system; rather it sets out the stages at which tests are required and the subjects, location and purpose of each stage. Inspection of incoming goods and components, and subassembly testing, shall be undertaken by the Concessionaire in accordance with the procedures set out in the Concessionaire's own Quality Management Plan and are not described here.

## XI. Responsibilities for Testing & Commissioning

**a.** All test documentation associated with a subsystem or system test shall be submitted for review by the Employer's Representative at least 30 days prior to the scheduled commencement of the associated test.

**b.** The Concessionaire shall revise and re-submit any documents to which the Employer's Representative has raised an objection such that all test documentation associated with any testing has achieved letter of no objection from the Employer's Representative prior to the commencement of the corresponding testing.

**c.** The Concessionaire shall successfully carry out all pre-tests according to the finalized test procedures and correct any errors prior to any (associated) witnessed acceptance tests.

**d.** The Concessionaire shall produce permanent records of all test progress and results in a formal systematic manner and submit to the Employer's Representative for his review.

**e.** The Concessionaire shall carry out all remedial work and re-testing found to be necessary in order that equipment shall pass the tests.

**f.** Each of the above responsibilities shall be discharged to the satisfaction of the Employer's Representative, but no objection by the Employer's Representative shall not imply any diminution of the Concessionaire's responsibilities.

## XII. Production Testing

**a.** Inspection - Inspection of incoming goods and component, and subassembly tests, shall be performed in accordance with the Concessionaire's Quality Management Plan and shall include software production and integration testing.

**b.** Product Inspection - Concessionaire's System Integration Testing - This is the Concessionaires own internal and un-witnessed testing on the complete ITCS System, including all simulation programs necessary to prove the totality of functionality, prior to offering them up to the customers witnessed test(s).

## XIII. Acceptance

**a.** The Concessionaire shall complete all relevant Production testing before offering any Item, Subsystem or the System as a whole for any witnessed acceptance test. All documentation covering the results of Production tests shall be referenced in the notice of witness testing submitted by the Concessionaire. The acceptance test stages follow the requirements of the GS clauses of the contract.

**b.** All parts subject to wear, such as electromechanical peripherals, may be omitted from the tests if agreed by the Employer's Representative. The printing and recording equipment needed for conducting the test shall be run throughout the test. All refills should be supplied during the period up to final handing over.

**c.** Tests shall be conducted to prove the individual and integrated functioning of the system hardware and demonstrate performance in the face of various contingencies.

**d.** Integrated system tests shall be conducted to prove the functionality of all applications software in the context of the complete integrated system, equipment and software configuration. The Concessionaire shall develop system test

## XIV. Training

**a.** The Concessionaire shall provide training to Employer's staff. The training should be designed for few different levels of staff viz. operator of the system and engineers/technical managers.

**b.** Concessionaire shall train the following minimum staff of EMPLOYER.

Operator staff — 30 Nos.

Engineers/ Managers- 5 Nos.

**c.** The Man weeks required for training of above staff shall be indicated by the ITCS Concessionaire in their BID.

**d.** Operator training will be carried out on site and at the supplier's own training school, as required.

**e.** Engineer/ Manager Training should concentrate on making them familiar with the capabilities of the system so they he can take full advantage of the ITCS in running station building.

**f.** They should be trained for system administration i.e. allocating passwords and password levels, adding points to, and deleting points from, the system, setting up management reports on energy usage, cost and efficiency for major plant items, defining load shedding priorities and so on.

## XV. Input/output List (Indicative)

The ITCS system shall provide monitoring and control of the following sub systems, as specified in the respective clauses of this specification. It is the responsibility of the Concessionaire to interpret the entire requirements of the specification and to provide input/output interfaces as required which may be described separately throughout this specification.

| SN | I/O | Source | Event | Remarks |
|---|---|---|---|---|
| | **Analog Inputs** | | | |
| 1 | Fire water line pressure | Jockey Pumps | | THROUGH VFC |
| 2 | SCR Temp | | | THROUGH VFC |
| 3 | SCR Humidity | | | THROUGH VFC |

| | | | | |
|---|---|---|---|---|
| 4 | TPER temp. | | | THROUGH VFC |
| 5 | TPER Humidity | | | THROUGH VFC |
| 6 | TER temp. | | | THROUGH VFC |
| 7 | TER humidity | | | THROUGH VFC |
| 8 | Lux Level | | | THROUGH 4-20 MA |
| | **Electrical Panels** | | | Energy Meter |
| 1 | Voltage-Phase 1 | | | Through RS 485 |
| 2 | Voltage – Phase 2 | | | Through RS 485 |
| 3 | Voltage – Phase 3 | | | Through RS 485 |
| 4 | Frequency | | | Through RS 485 |
| 5 | PF-3 Phase equivalent | | | Through RS 485 |
| 6 | Current-3 Phase equivalent | | | Through RS 485 |
| 7 | Current - Phase 1 | | | Through RS 485 |
| 8 | Current - Phase 2 | | | Through RS 485 |
| 9 | Current - Phase 3 | | | Through RS 485 |
| 10 | Power factor 3 phase equivalent active power | | | Through RS 485 |
| 11 | Power factor 3 phase equivalent Reactive Power | | | Through RS 485 |
| 12 | Power factor 3 phase equivalent Apparent power | | | Through RS 485 |
| 13 | Energy 3 phase equivalentActive Energy | | | Through RS 485 |
| 14 | Energy 3 phase equivalent Apparent Energy | | | Through RS 485 |
| | **UPS** | | | |
| 15 | Input Voltage | | | Through RS 485 |
| 16 | Battery Voltage | | | Through RS 485 |
| 17 | Charging Current | | | Through RS 485 |
| 18 | Output Voltage | | | Through RS 485 |
| 19 | Output Frequency | | | Through RS 485 |

| | | | | |
|---|---|---|---|---|
| 20 | Load % | | | Through RS 485 |
| 21 | Bypass Voltage | | | Through RS 485 |
| 22 | Bypass Frequency | | | Through RS 485 |
| | **Battery Charger (ESR)** | | | |
| 23 | Input Voltage | | | Through RS 485 |
| 24 | Battery Voltage | | | Through RS 485 |
| 25 | Charging Current | | | Through RS 485 |
| 26 | Output Voltage | | | Through RS 485 |
| **Digital Input** | | | | |
| | DG set | | | |
| 1 | DG set ON | | | Through RS 485 |
| 2 | DG set OFF | | | Through RS 485 |
| 3 | DG set TRIP alarm | | | Through RS 485 |
| 4 | DG room exhaust fan ON status | | | Through RS 485 |
| 5 | DG room exhaust fan OFF Status | | | Through RS 485 |
| 6 | DG room Fresh air fan ON Status | | | Through RS 485 |
| 7 | DG room Fresh air fan OFF Status | | | Through RS 485 |
| 8 | Auto/Manual switch | | | Through RS 485 |
| 9 | Lube Oil pressure low Alarm | | | Through RS 485 |
| 10 | Engine water temp high Alarm | | | Through RS 485 |
| 11 | DG set Battery voltage Low alarm | | | Through RS 485 |
| 12 | DG fuel low level | | | Through RS 485 |
| 13 | DG fuel high level | | | Through RS 485 |
| | **Pumps** | | | |
| 14 | Raw Water Pump 1 Run Status | | | Through Voltage free contact (VFC) |
| 15 | Raw Water Pump1 Auto/ Manual Switch Status | | | THROUGH VFC |

| | | | | |
|---|---|---|---|---|
| 16 | Raw Water Pump2 Run Status | | | THROUGH VFC |
| 17 | Raw Water Pump2 Auto/ Manual Switch Status | | | THROUGH VFC |
| 18 | Domestic Water Pump 1 Run Status | | | THROUGH VFC |
| 19 | Domestic Water Pump1 Auto/ Manual switch Status | | | THROUGH VFC |
| 20 | Domestic Water Pump2 Run Status | | | THROUGH VFC |
| 21 | Domestic Water Pump2 Auto/ Manual switch Status | | | THROUGH VFC |
| 22 | Tube well Pump1 Run Status | | | THROUGH VFC |
| 23 | Tube well Pump1 Auto/ Manual Switch Status | | | THROUGH VFC |
| 24 | Tube well Pump2 Run Status | | | THROUGH VFC |
| 25 | Tube well Pump2 Auto/ Manual Switch Status | | | THROUGH VFC |
| 26 | Fire Pump 1 Run Status | | | THROUGH VFC |
| 27 | Fire Pump1 Auto/ Manual Switch Status | | | THROUGH VFC |
| 28 | Fire pump2 Run Status | | | THROUGH VFC |
| 29 | Fire Pump2 Auto/ Manual Switch Status | | | THROUGH VFC |
| 30 | Jockey Pump1 Run Status | | | THROUGH VFC |
| 31 | Jockey Pump1 Auto/ Manual Switch Status | | | THROUGH VFC |
| 32 | Domestic water tank1 25% level | | | THROUGH VFC |
| 33 | Domestic water tank1 50% level | | | THROUGH VFC |
| 34 | Domestic water tank1 75% level | | | THROUGH VFC |
| 35 | Domestic water tank1 100% level | | | THROUGH VFC |
| 36 | Domestic water tank2 25% level | | | THROUGH VFC |
| 37 | Domestic water tank2 50% level | | | THROUGH VFC |

| | | | | |
|---|---|---|---|---|
| 38 | Domestic water tank2 75% level | | | THROUGH VFC |
| 39 | Domestic water tank2 100% level | | | THROUGH VFC |
| 40 | Flushing water tank1 25% level | | | THROUGH VFC |
| 41 | Flushing water tank1 50% level | | | THROUGH VFC |
| 41 | Flushing water tank1 75% level | | | THROUGH VFC |
| 42 | Flushing water tank1 100% level | | | THROUGH VFC |
| 43 | Flushing water tank2 25% level | | | THROUGH VFC |
| 44 | Flushing water tank2 50% level | | | THROUGH VFC |
| 45 | Flushing water tank2 75% level | | | THROUGH VFC |
| 46 | Flushing water tank2 100% level | | | THROUGH VFC |
| 47 | Fire water tank 1 25% level | | | THROUGH VFC |
| 48 | Fire water tank 1 50% level | | | THROUGH VFC |
| 49 | Fire water tank 1 75% level | | | THROUGH VFC |
| 50 | Fire water tank 1 100% level | | | THROUGH VFC |
| | Road Tunnel Lighting/ External Lighting | | | |
| 51 | Status of MCCB operating Road Lighting LDB | | | THROUGH VFC, Microprocessor Based Release |
| 52 | Status of Concessionaire operating Road Lighting LDB | | | THROUGH VFC, Microprocessor Based Release |
| 53 | Status of Concessionaire operating External Lighting | | | THROUGH VFC, Microprocessor Based Release |
| | **MDB (RS485)** | | | |
| 54 | Incomer #1 On status | | | THROUGH VFC, Air Circuit breaker Based Release |

| | | | | |
|---|---|---|---|---|
| 55 | Incomer #1 OFF status | | | THROUGH VFC, Air Circuit breaker Based Release |
| 56 | Incomer #2 On status | | | THROUGH VFC, Air Circuit breaker Based Release |
| 57 | Incomer #2 OFF status | | | THROUGH VFC, Air Circuit breaker Based Release |
| 58 | Bus Coupler On Status | | | THROUGH VFC, Air Circuit breaker Based Release |
| 59 | Bus Coupler On Status | | | THROUGH VFC, Air Circuit breaker Based Release |
| 60 | Incomer #1 Shunt Trip status | | | THROUGH VFC, Air Circuit breaker Based Release |
| 61 | Incomer #2 Shunt Trip status | | | THROUGH VFC, Air Circuit breaker Based Release |
| 62 | Bus CouplerShunt Trip status | | | THROUGH VFC, Air Circuit breaker Based Release |
| | **EPP (RS485)** | | | |
| 63 | Incoming MCCB from DG AMF Panel on Status | | | THROUGH VFC, Microprocessor Based Release |
| 64 | Incoming MCCB from DG AMF Panel on Status | | | THROUGH VFC, Microprocessor Based Release |
| 65 | Incoming MCCB from DG AMF Panel Shunt Trip Status | | | THROUGH VFC, Microprocessor Based Release |
| 66 | Incoming MCCB from MDB Panel On Status | | | THROUGH VFC, Microprocessor Based Release |

| | | | | |
|---|---|---|---|---|
| 67 | Incoming MCCB from MDB Panel OFF Status | | | THROUGH VFC, Microprocessor Based Release |
| 68 | Incoming MCCB from MDB Panel Shunt Trip Status | | | THROUGH VFC, Microprocessor Based Release |
| | **A/C PANEL** | | | |
| 69 | Incoming MCCB On Status | | | THROUGH VFC, Microprocessor Based Release |
| 70 | Incoming MCCB OFF Status | | | THROUGH VFC, Microprocessor Based Release |
| 71 | Incoming MCCB Shunt Trip Status | | | THROUGH VFC, Microprocessor Based Release |
| | PA PANEL | | | |
| 72 | Incoming MCCB On Status | | | THROUGH VFC, Microprocessor Based Release |
| 73 | Incoming MCCB OFF Status | | | THROUGH VFC, Microprocessor Based Release |
| 74 | Incoming MCCB Shunt Trip Status | | | THROUGH VFC, Microprocessor Based Release |
| | **FWP PANEL** | | | |
| 78 | Incoming MCCB On Status | | | THROUGH VFC, Microprocessor Based Release |
| 79 | Incoming MCCB OFF Status | | | THROUGH VFC, Microprocessor Based Release |
| 80 | Incoming MCCB Shunt Trip Status | | | THROUGH VFC, Microprocessor Based Release |
| | **WPP PANEL** | | | |

| | | | | |
|---|---|---|---|---|
| 81 | Incoming MCCB On Status | | | THROUGH VFC, Microprocessor Based Release |
| 82 | Incoming MCCB OFF Status | | | THROUGH VFC, Microprocessor Based Release |
| 83 | Incoming MCCB Shunt Trip Status | | | THROUGH VFC, Microprocessor Based Release |
| | **UPS** | | | |
| 84 | Main failure alarm | | | THROUGH RS 485 |
| 85 | No load | | | THROUGH RS 485 |
| 86 | Low battery alarm | | | THROUGH RS 485 |
| 87 | System fault | | | THROUGH RS 485 |
| 88 | Overload | | | THROUGH RS 485 |
| 89 | Over temperature | | | THROUGH RS 485 |
| 90 | Bypass mode for Inverter | | | THROUGH RS 485 |
| 91 | Mains ON | | | THROUGH RS 485 |
| 92 | Mains faulty | | | THROUGH RS 485 |
| 93 | Inverter ON/OFF | | | THROUGH RS 485 |
| 94 | Inverter faulty | | | THROUGH RS 485 |
| 95 | Bypass mode for battery | | | THROUGH RS 485 |
| | **Battery Charger (ESR)** | | | |
| 96 | Mains ON | | | THROUGH RS 485 |
| 97 | Charging/ discharging/boost charging status | | | THROUGH RS 485 |
| 98 | Battery low status | | | THROUGH RS 485 |
| 99 | Mains failure alarm | | | THROUGH RS 485 |
| 100 | Low battery alarm | | | THROUGH RS 485 |
| 101 | Overload and over temperature alarm | | | THROUGH RS 485 |
| **Digital Output** | | | | |

| | | | | |
|---|---|---|---|---|
| | Pump | | | |
| 1 | Raw Water Pump1 Start | | | THROUGH VFC, Microprocessor Based Release |
| 2 | Raw Water Pump1 Stop | | | THROUGH VFC, Microprocessor Based Release |
| 3 | Raw Water Pump2 Start | | | THROUGH VFC, Microprocessor Based Release |
| 4 | Raw Water Pump2 Stop | | | THROUGH VFC, Microprocessor Based Release |
| 5 | Domestic Water Pump 1 Start | | | THROUGH VFC, Microprocessor Based Release |
| 6 | Domestic Water Pump 1 Stop | | | THROUGH VFC, Microprocessor Based Release |
| 7 | Domestic Water Pump 2 Start | | | THROUGH VFC, Microprocessor Based Release |
| 8 | Domestic Water Pump 2 Stop | | | THROUGH VFC, Microprocessor Based Release |
| 9 | Tube well Pump1 Start | | | THROUGH VFC, Microprocessor Based Release |
| 10 | Tube well Pump1 Stop | | | THROUGH VFC, Microprocessor Based Release |
| | **DG SET** | | | |
| 11 | DG start | | | THROUGH RS 485 |
| 12 | DG stop | | | THROUGH RS 485 |
| | **ESPP/A/CP** | | | |
| 13 | Incomer ON | | | THROUGH VFC, Microprocessor Based |

| | | | | |
|---|---|---|---|---|
| | | | | Release |
| 14 | Incomer OFF | | | THROUGH VFC, Microprocessor Based Release |

## XVI. Automation

a) When water level becomes lower than a predefined mark, pump will startto fill it.

b) When water level reaches to up-to-mark, pump will stop.

c) Fire water level will not be less than 90%, at such situation Tube well pump will start and alarm will be generated.

d) If main water supply pump fails, then standby pump shall be started automatically.

e) Based on the detailed design, the Concessionaire shall develop a detailed ITCS input/output point list for all equipment's to be monitored and/or controlled subject to the approval of the Employer's Representative.

f) Control and monitoring shall be provided primarily at the TCR. It shall be possible, however, to enable secondary control and monitoring of equipment's from TCC

g) Description of basic functions is given in Table below:

| **Category** | **Functions** | |
|---|---|---|
| | **Specified Categories** | **Description** |
| Monitor and Supervision | CRT- based supervision | Window functions are available, enabling display of plural supervisory Screen at thesame time. |
| | 1) Status display of units | Displaying position symbol of units withthe shape, color, flickering |
| | 2) Fault Display | Displaying position symbol of units withthe shape, color, flickering |
| | 3) Telemetry value display | Display major telemetry values of voltage, current etc. |
| | 4) Ready for command | Graphics colour will be yellow |
| | 5) Running status | Graphics colour for green |
| | 6) High/Low limit check | Supervision and display of deviation ofvoltage, current and such telemetry data from High/Low setting values. |
| | 7) Trip | Trip status of the breaker will be shown by specific color (Red) |
| | Local | No control from ITCS workstation, graphics colour will become Red |
| | Remote/Auto | Workstation control available, Graphics colour becomes yellow. In auto state controlled by predefined logic. |

| | | |
|---|---|---|
| | 1) Reporting management | Automatic collection of various achievement data for editing and listing of operational achievement documents. |
| | a) Daily Report | Reporting and printing out a daily report of data arising from hourly telemeter and incidence occurrence |
| | b) Monthly Report | Reporting and printing out a monthly report of data arising from daily report |
| | c) Annual Report | Reporting and printing out an annual report of data arising from Monthly report |
| | 2) Message summary record | Reporting and printing out a message list, supported by sorting and editing functions based on specific factors, such as time and facilities. |
| | a) Message list Record | Reporting the contents of equipment operation status change and alarming |
| | b) Memo recording Screen | Reporting the contents of equipment operation status change and alarming |
| **Category** | **Functions** | |
| | **Specified Categories** | **Description** |
| Other Functions | 1) Change over remote control to manualcontrol and vice versa | Security protection by log-on password checks (operators, system managers,programmers) |
| | 2) Right of operation supervision and setting.<br>a) Security Protection<br>b) Operation Privilege setting | Setting up the scope of right-of –operationwith a user name to cover supervisory control objectives. |

**Note:** All software needed for proper functioning/operation shall be supplied by the Concessionaire with adequate license and if any supplied software goes defunct by any way,the same shall be restored by the Concessionaire during defect liability period free of cost.All software to be supplied shall be latest version at the time of tender.

### 7.2.14 Closed Circuit Television System

#### 1. General

The tunnels shall have CCTV cameras for continuous monitoring on the vehicular movement which will be linked to central control system. Camera shall be IP type. The CCTV will provide also support to early detect a fire inside the tunnel and to verify alarms coming from the automatic fire detection systems. CCTV system shall be provided with image analysis function to detect incidents (Video Incidents Detection System), wrong-way driving, car stopped or other anomalous conditions. The portals and external areas will be equipped with minimum two sets of dome dynamic colour video camera. Inside the tunnel sets of zoom dynamic auto iris colour video cameras shall be installed with a regular distance of (minimum) 150 meters. A detailed study of coverage shall be provided by the Concessionaire in order to have full coverage inside the main tunnel and the most critical area (layby, cross passages etc.). Considering the importance of data and to store large amount of data securely, Network Video Recorder system shall be provided.

The CCTV System allows the tunnel operator a surveillance of the situation and the conditions inside the tunnel and at the free field areas. Thus, the operator is able to recognize abnormal conditions and can inform the people in the tunnel via the Public Address System.

CCTV cameras shall be installed within the tunnel tube and outside the tunnel:

- Inside the main tunnel tube: fixed cameras
- In front of the main tunnel portals: fixed outside cameras.
- The outside cameras shall be mounted on a column at a height of 5 m.
- In front of the portals of the Accesses: outside Dome Cameras

The outside cameras shall be mounted on a column at a height of 5 m. The direction orders shall be controlled from the Control Centre or Equipment Room (Control Panel).

The video signals shall be transmitted via multiplexers to the equipment Room / Control Room and further via optical fiber cables to the tele control system (SCADA). Between the cameras and the multiplexer Ethernet cable shall be provided. Optical fibre cable cores shall have a wavelength of 1310 to 1550 nm. At the equipment Room / Control Room the signals shall be presented/prepared and demultiplexed.

Generally, all pictures shall be available at the Control Centre.

In the Control Centre, the provided CCTV-screens (e.g. 5 pieces.) shall be available for supervising the tunnel inclusive portal areas/ etc. Five of the CCTV-screens shall show fixed pictures of the tunnel (about every 1000 m), the main portals and the access portals. The no. of screens shall be finalized by EPC / EM Concessionaire as per final design to suit site requirements.

One of the provided screens shall be defined as emergency screen. The emergency screen shall show the emergency / alarm image, which shall be switched on automatically if an incident occurs, therefore a separate output of the CCTV-picture switchboard shall be available, where the emergency / alarm screen shall be connected.

The other screens shall be freely selectable showing any chosen picture. So every picture shall be available on every screen to make all pictures / screen combinations selectable and re-programmable from the local CCTV Control Panel, manually.

At the equipment Room / Control Room and also CCTV-screens (alarm screens) shall be provided.

There shall be a digital video recording unit at the Control Room which records all camera pictures continuously and stores (records) the signal of the camera activated under alarm condition automatically (emergency / alarm picture).

With the aid of the colour CCTV System, the operator(s) at the Control Centre shall have clear, intelligible visual information of the tunnel.

The quality of pictures displayed on the screens shall permit the recognition of person's activity (e.g. repair work, running persons, etc.) clearly at any point within the tunnel.

The cameras (and screens) shall be of solid state-type, modular components shall be employed where practical and the circuitry shall be assembled in such a way that instructed staff can replace defective modules easily.

AII equipment shall be protected from damage by lightning surges and over voltages. An intelligent video control system shall be provided.

The interface between the CCTV-System and the Tunnel Control System is the video switch port, and prevent system faults from causing a deterioration of the monitoring functionality, the whole system shall be designed to have a high degree of availability.

Anywhere in the CCTV System a failure or a malfunction occurs, this must not have any defects / repercussions to any other parts of the CCTV System.

The CCTV System described in these specifications shall meet the following minimum performance standards.

## 2. Scope Of Work

The CCTV system for tunnel shall have outdoor fixed box cameras installed at every 150m interval along the entire length of the tunnel. There shall be 2 HD outdoor PTZ cameras at both portals of the tunnel.

The CCTV system shall have a Video Management Software with redundant Management Servers. The primary management server shall be installed at Control station -1 and Backup management server shall be placed at Control

station - 2 to provide HOT redundancy at management server level between Control station -1 and Control station - 2. There shall be multiple recording servers at Control station -1, each recording server capable of handling suitable cameras. All cameras shall be configured to provide live view at 1080p, 25fps with H. 264 compression. All cameras shall be recorded for minimum 30 days 24x7 at 1080p, 25fps with H.264 compression. All recordings shall be done inside the Control station.

Control station - 2 shall act as disaster recover (DR) site of Control station -1. Control station -2 will have Backup management server, three recording servers and storage for 30 days similar to Control station -1. The second video stream at 1080p, 25fps with H.264 compression for all cameras shall be configured in three recording servers at Control station -2. All cameras shall be recorded for minimum 30 days at Control station -2 and the recordings shall be used in case of failure of Control station -1. When there is no motion in the field of view of the camera, the recordings shall happen at 1080p, 5fps with H.264 compression. In case of motion is detected by the camera, recordings shall happen at 1080p, 25fps with H.264 compression. The system shall have pre-recorded and post record feature configurable for each camera from 5 sec to 60 sec. All secondary recordings shall be done inside the Control station.

All cameras inside the tunnel shall have IR of 100m illumination range to cover entire tunnel.

Video analytics shall be configured on the cameras inside the tunnel. Software based Video Analytics shall be preferred. There shall be additional servers for Video Analytics. The EM Concessionaire shall provide full compliance on technical specification of VMS and cameras as given below:

- CCTV Cameras
- Camera distribution boxes
- Multiplexers / Demultiplexers
- Video Switch
- Video amplifier
- CCTV picture switchboard at Control Room
- CCTV control panel at the Control Centre
- CCTV screens at the Control Centre
- Video recording unit
- Video detection unit
- Cabling
- Camera Column

## 3. Technical Specifications-CCTV Cameras

The camera shall be a colour CMOS type. It shall be capable of operating under a wide range of lighting conditions, varying from brilliant sunshine to night-time with minimal lighting.

Each camera shall allow any alphanumeric insert text into the picture. The text shall consist of at least 10 digits, adjustable by at least two buttons. Each digit can be a number or letter, which shall define the position of the camera for example by km - chainage.

Each IP based fixed camera unit shall consist of a CCTV camera, camera housing with a mounting bracket and a heating unit. The dome camera in the free field area shall be vandal-proof camera with pan/ tilt and zoom function.

## 4. Video Management System

The Video Management System (VMS) shall be a scalable Microsoft Windows-based video management and surveillance system consisting of four primary components, as follows:

- A core server application to maintain the database of cameras and recording devices and to provide a web-based administrative portal to manage the video surveillance system
- A media gateway application to route video traffic to users as requested and appropriate
- A client presentation application to allow users to view and manage live and recorded video.
- A storage management application server to manage the video storage resources on the network.

**SYSTEM FUNCTIONS AND CAPABILITIES**

The VMS shall be designed for reliability through fault-tolerant, distributed architecture, and multiple levels of redundancy.

The VMS shall provide an open interface that facilitates the creation and deployment of user interface plug-ins including mapping, video information overlays, access control, and license plate recognition.

**VIDEO CAPABILITIES**

Support recording of MJPEG, MPEG-4 and H.264 IP video streams

Support megapixel video cameras up to 28 Megapixel resolution

Support for ONVIF S and G profiles

Aggregate independent VMS deployments across multiple networks and manage all video through a single system while preserving local operation.

Analytic capabilities integral to VMS

- Motion - Detection of objects that move within, enter, or exit a scene and triggering an event
- Alarm - Detection of physical alarms from cameras within the system, triggering an event
- Each VMS component shall operate on standard commercial off-the-shelf (COTS) hardware.
- VMS software updates shall be downloadable from a publicly available website.
- The VMS shall indicate system performance and operation status utilizing a variety of reports including csv and pdf formats.

The Manufacturer shall offer a mobile application with the capability to access live video from up to 500 cameras.

**CORE SERVER APPLICATION**

The core server application shall have central management responsibility, with the following functions and characteristics:

- Maintain a database of cameras and recording devices
- Provide an administrative Web interface
- Define and administer level user accounts, their associated roles, and permissions for the system functions and devices users can access
- Provide basic access to video streaming resources, ensuring that users with appropriate permissions can view video from the system without installed video client software
- Continually search the network for relevant devices
- Assign resources to video recording pools
- Store videos that operators elect to export from network storage devices for safe keeping, supporting the storage of video clips relevant to an investigation independent of standard recording devices
- Create and assign “tags” to efficiently organize cameras and devices within the system
- Configure and respond to events within the system
- Download reports from the system in csv format contained within a ZIP archive
- Perform daily backup at a specified time

**DEPLOYMENT OPTIONS:**

Independent core server working with an independent media gateway application server to provide systems functions

- combined single server also hosting the media gateway application
- distributed cluster to provide fault tolerance, scalability and load balancing
- virtual machine

## 5. Hardware Requirements

- Processor: Intel i-3, i-5 or latest
- Operating System: Microsoft Windows 2012 Server / Windows 8/10 or latest
- RAM: 32 GB DDR RAM ECC
- SSD Storage: 480 GB
- HDD: 2 TB
- Video
- Graphics: Intel HD Graphics P47400
- Outputs:
- Display Port (2)
- DVI-D
- VGA
- Resolution Capability:
- Display Port: 3840 x 2160 @ 60 HZ
- DVI-D, VGA: 1920 x 1200 @ 60 HZ

**MEDIA GATEWAY APPLICATION**

Based on a successful determination by the core server application of a user's permissions, the media gateway connects the user with the appropriate camera, encoder, or recorder device.

The media gateway shall be deployed within the VMS in modular fashion to allow expansion of system capabilities or to build redundancies within the system to maximize video availability.

**DEPLOYMENT OPTIONS:**

- Independent core server working with an independent core server application to provide systems functions
- combined single server also hosting the core server application
- virtual machine

**CLIENT APPLICATION**

The Client application shall be Windows-based, providing an environment from which authorized users can watch live and recorded video on a computer in which the application has been installed.

The Client shall be comprised of a main control panel, which may be hidden, working in unison with a series of windows (workspaces), each providing a tab-based experience.

**WORKSPACES AND TABS**

- The Client interface shall be based upon workspaces and tabs.
- A tab shall be a configurable layout populated with sources of content and plug-ins contained in cells.
- A collection of one or more tabs shall constitute a workspace.
- The Client shall allow configuration and recall of complete workspaces.
- An operator with appropriate permissions shall be able to send a saved workspace to other clients, causing their system to launch the saved workspace.
- Any layout of video can be saved as tab to be later recalled by an operator.

An operator with appropriate permissions shall be able to send a saved tab to other clients, causing their system to launch the saved tab.

Cells shall have the capability for system management, live view, and playback search options.

Remote Tab Push: an operator with appropriate permissions can choose to send a saved tab one or more operators' clients, causing their system to launch the saved tab.

**6. Live View and Playback**

A list of video and audio sources which users are authorized to access shall be displayed.

The client computer shall be able to connect to an unlimited number of recorders simultaneously to display live and recorded video.

The client shall allow video streams to be selectable from a system tree on an individual camera, individual system, client defined local groups, or from pre-defined recorder-based groups.

Users shall be able to seamlessly switch between live and recorded video on the fly.

**LIVE VIEW**

For live view, cells 1/4 the size of the tab or larger will use the primary stream from a video source, and cells smaller than 1/4 the size the tab shall use the secondary video stream.

**7. Pan Tilt Zoom (Ptz)**

Digital Zoom - An operator shall be able to digitally zoom in a video stream in live or playback mode.

Optical Zoom and Pan Tilt Control: Operators shall be able to use a mouse or joystick to control PTZ cameras.

**PLAYBACK**

The Client application shall enable simultaneous playback for up to (9) synchronized cameras.

The Client application shall have the capability to playback non-synchronized cameras at one time in different cells.

For viewing recorded video, cells 1/4 the size of the tab or larger shall display full-frame rate video, and cells smaller than 1/4 the size of the tab shall playback only I-Frames to conserve bandwidth and processing power.

When hovering over a recorded video time bar, an operator shall see a thumbnail representing the contents of the video stream at that point in time.

Available playback control functions:

- date-time selection
- synchronized playback of selected cells within a tab
- play video at normal speed
- pause video and advance one frame
- pause video and rewind one frame
- fast forward video at speeds up to 16x
- rewind video at speeds up to 16x
- rewinds video 30 seconds and initiates playback
- forward video to live playback
- take snapshot of the current frame

Hovering over a video playback cell with a mouse shall display the playback control menu.

**INVESTIGATIONS**

An investigation mode shall be available to provide a 2 x 2 layout with synchronized playback controls, allowing users to fully investigate a scene from multiple angles.

- The investigation mode shall open in a new tab.

The investigation mode shall enable operators to synchronize video playback and export investigative playlists covering scenes of interest in forward or reverse at speeds up to 128 times normal playback.

Users shall be able to create playlists from multiple video clips encompassing selected scenes from an investigation.

Operators shall be able to save a current investigation, preserving the associated device list and any created clips for later recall.

- Saved investigations shall be capable of being shared with other operators' similar tabs.

Operators shall be able to export individual video clips or entire playlists to the Core application, storing clips relevant to their investigation independent of the system's network video storage for evidentiary safe-keeping and quick access.

**EXPORT**

An operator shall be able to create and export a JPG snapshot image of the current frame of video in a cell.

The Client application shall enable video export to any system-accessible media including locally to HDD, CD/DVD, Flash USB device or to network storage.

- Exported video shall be subject to check sum verification.

**DISPLAY**

- The Client application shall have both built in video decoding and the ability control separate hardware video decoders, providing virtual matrix functionality.
- The Client application shall allow multiple monitor support for up to 6 displays per client workstation, with the use of hardware video decoders.
- The Client application shall allow up to 4 1080p, 30 fps streams per monitor.

**EVENTS**

- The Client application shall have an operator to respond to events.
- Certain events shall be configurable for acknowledgement.

**ACKNOWLEDGEMENT OPTIONS:**

- snooze
- in process
- acknowledged
- Authorized operators shall have the ability to derive additional information about an event from the core application.
- Plug-ins – The Client application shall support modular plug-ins for enhanced functionality.
- System and Device Information

**Information management**

- The Client application shall provide a mechanism to create and assign
- A primary device list shall be apparent in the Client application.

The device list shall be sortable by device name or device ID.

The device list shall be able to be filtered by the following terms:

- simple text-based filter, matching the device name or device ID
- tag-based filtering, showing devices matching the intersection of all assigned tags
- status-based filtering, showing devices with a particular status

User Roles, as assigned by a System Administrator, shall define the limits of a user's ability to access live or recorded video and to export video and other standard client operations.

Authorized users shall be able to share views, including window arrangements and camera selections, with other users, for purposes of collaboration.

When using a mouse to hover over a device in a listing, a popup shall appear with the following information:

- Device state
- Device name
- Device ID
- Thumbnail image
- Associated tags

- IP Address

**Hardware Requirements:**

- Processor: Intel i-3, i-5 or latest
- Operating System: Microsoft Windows 7 Ultimate SP3 / Windows 8/10 or latest
- RAM: 32 GB DDR RAM ECC
- SSD Storage: 480 GB
- Optical Drive: DVD ± RW
- Video
- Graphics: Intel HD Graphics P47400
- Outputs:
- Display Port (2)
- DVI-D
- VGA
- Resolution Capability:
- Display Port: 3840 x 2160 @ 60 HZ
- DVI-D, VGA: 1920 x 1200 @ 60 HZ

**8. Storage Management Application Server**

The storage management application server shall incorporate both server functions and storage elements into a purpose-built chassis.

The storage management application server shall not require removal from its rack installation when hard disk drives or power supplies must be replaced.

The storage management application shall record video and audio streams from IP cameras and video encoders on the network.

Video:H.264 in High, Main, or Base Profile streams from both standard resolution and megapixel cameras

The storage management application shall have the following further functions and characteristics:

- Employ the Windows Server 2012 operating system
- Use RAID 6 parity across the storage drives to protect recorded data against a hard disk drive failure
- Use enterprise-level hard disk drives specifically rated for operation in RAID systems
- Employ the following redundancy features
- redundant, hot swappable power supply modules
- redundant, hot swappable system fans

Designed for online service and maintenance and cannot be removed from the rack when hard disk drives or power supplies must be replaced.

**Guaranteed recording throughput:** 450 Mbps and up to 300 total cameras per storage device under normal and error (RAID rebuild) conditions

Guaranteed downloading throughput: 175 Mbps per storage device under normal and error (RAID rebuild) conditions.

- The storage server shall natively support Optera cameras any combination of cameras from third-party manufacturers supporting ONVIF Profile S.
- Support continuous, scheduled, alarm/event (including analytic), and motion
- Pre- and -post alarm periods shall be configurable
- Support bookmarking of video content

- Support privacy tools that allow administrators to establish maximum retention times for video
- Ability to report all diagnostic events, including software status diagnostics to a centralized user interface
- Fully manageable from a remote workstation, including the ability to configure settings and update firmware and software Capable of interfacing with a UPS using a USB connector
- The network video recorder shall receive status and control signals from the UPS when it is in backup mode, informing the operator about the amount of charge remaining and triggering a controlled shutdown when the charge becomes zero.

**Hardware**

- System Specifications
- System Drive: 200 GB SSD
- RAID Level: RAID 6
- Storage: Up to 96 TB
- Drive Interface: SAS/SATA II
- Network Interface (2): Gigabit Ethernet 1000Base-T (RJ-45 connection)
- USB 2.0:2 on rear panel; 2 on front panel
- USB 3.0:2 on rear panel
- Electrical - Power
- Voltage Input: 100 to 240 VAC, 50/60 Hz, auto ranging
- Power Supply: Internal, dual-redundant, hot-swappable
- Environmental
- Temperature
- Operating: 10° to 35°C (50° to 95°F) at unit intake
- Storage: -40° to 65°C (-40° to 149°F)
- Operating Humidity: 20% to 95%, non-condensing
- Mounting: Desktop (feet); Rack, 3 RU per unit

**3D Mouse Controller**

i. The 3D Mouse must be compatible with all network video management components.

ii. Six-degrees-of-freedom sensor – Intuitively and precisely navigate digital models or camera positions in 3D space.

iii. Advanced ergonomic design – The full-size, soft-coated hand rest positions the hand comfortably, and 15 large, soft-touch, function keys allow quick access to frequently used commands.

iv. Quick View Keys – Fingertip access to 12 views makes it easier to switch cameras.

v. Intelligent Function Keys – Easy access to 4 application commands for an optimized workflow.

vi. On-Screen Display – Provides a visual reminder of function key assignments on your computer screen.

vii. 3D Space Mouse Modifiers – Fingertip access to Ctrl, Shift, Alt and Esc keys saves time by reducing the need to move your hand between mouse and 3D Mouse.

viii. Virtual Num Pad – Allows direct numerical input into your application using your standard mouse rather than the 3D Mouse.

ix. The 3D Mouse must be part of an integrated system and shall be configured so any number can be added to the system. When combined with user interfaces (UIs), network storage managers (NSM's), encoders, IP cameras, and video consoles, the 3D Mouse forms an integral part of a complete network-based video control system.

**x. Hardware**

- Power Supply

- Input Connector Type: Universal, interchangeable
- Connectivity
- 3D Space Mouse Interface: USB2.0
- Cable: USB
- Module Specifications
- 3D Space Mouse Keypad
- Joystick: Fully proportional PTZ, variable speed; with zoom, iris, and focus controls
- Environmental
- Operating Temperature: 0° to 40°C (32° to 104°F) air intake of unit
- Storage Temperature: –40° to 65°C (–40° to 149°F)

**9. Enterprise and Scalable Management Platform**

The VMS shall be an enterprise solution and scalable to support unlimited number of cameras. VMS should support latest Windows Server operating system on Server machine. It should support latest Windows OS on Client machine, independent of what operating system is there in the servers. VMS should support SQL/ MySQL/ Oracle DBMS.

a. Distributed Architecture and Openness

The VMS shall support distributed video architecture which seamlessly integrates the video operations of numerous systems onto one virtual platform, allowing security operators to view and control all cameras, whether across a single facility or across the multiple locations. The VMS shall support ONVIF profile and integrate all cameras supporting ONVIF profile.

b. Standards for Software

The VMS shall be designed and developed to the following standards:

- ISO 9001-2008
- ISO/IEC 15504 Level 3 or higher (SPICE 2.0 Software Process Improvement and Capability Determination)
- SEI CMM Level 5 (American Software Engineering Institute - Capability Maturity Model)

c. Server-Client Architecture

The VMS shall have Enterprise Database servers, Recording Servers, Analytics Server, Storage and Operator workstations.

The VMS shall support minimum 2500 cameras managed per Enterprise Database Server. Systems shall be scalable by adding additional Servers.

The VMS shall have Analytics Servers dedicated to analyse video streams. The Analytics Servers shall process the live video using preconfigured rules and Intelligent Video Analytics algorithms to determine events of interest.

d. Fault Tolerant Architecture and Redundancy

The database server shall provide a central fault tolerant repository for all configurations and run time information for the complete system.

The VMS must be capable of running a pair of similarly configured Database Servers in a hot backup configuration where at any point in time, one is the acting Primary and the other is acting as the Hot Backup. The backup Database Server shall be continuously synchronized with the master Database Server to ensure that it is always up-to-date and ready for a fail-over, when required. The failover for Database Server should be seamless and should not affect recording of cameras.

It must be possible to remove one of the redundant systems for maintenance without interrupting operation, and upon its reinstatement, automatically re-synchronize the databases, again without interruption to system operation.

The VMS shall support Primary and Backup Recording Servers allowing N: 1 to N: N redundancy as per BOQ. The failover and fail back mechanism between Preferred and Backup Camera Servers shall be configurable and support both automatic and manual operation. The failover process for Recording Server should not take more than 10 sec.

e. Concurrent Web Clients and Console Stations

The VMS shall provide Internet Explorer Clients for users other than Operators in Command & Control Room. These clients will be used for viewing of cameras by Security Officers and other authorized users other than in Command & Control Room. Incident and alarm responses are not required for these clients.

The VMS shall provide a professional level Surveillance Console interface for control room operators. Its primary role shall be to meet the operational requirements related to surveillance.

f. Operational Features of VMS

The VMS console shall have a Navigation Pane that include separate tabs to display available cameras, Views, groups and locations available to the operator based on their security settings. It shall include a multi-level camera tree up to at least 5 layers deep with built-in filter search capability. It shall support user defined logical groups.

The VMS shall have flexible workspace with simultaneous display of Live and Recorded video from the same or different cameras. Information describing the camera and associated video shall be shown in the tile including camera name, camera number, camera health status and whether the camera is currently recording, replaying video, paused or playing live video.

The VMS shall have Wild-Card search feature for cameras in Camera Tree and Groups.

The VMS console shall have a timeline control to display and play back recorded video for one or more cameras. Playback shall be possible on 1 or more cameras simultaneously for all cameras currently displayed in the Video Workspace.

The Timeline toolbar shall include Play, Pause, Snapshot, Fast Rewind (up to 1024x), Frame Rewind, Fast Forward (up to 1024x), Frame Forward, Jump Back, Motion Search and Calendar Control as standard features.

The timeline will also have zooming and scrubbing feature for easy analysis of recorded videos.

The VMS console shall have Motion Search feature that allows searching for areas of motion in recorded video. The Motion Search feature shall provide the ability to define a region of interest for each camera currently included in the timeline. The region of interest will be displayed on the camera image in the Video Workspace and each shall be separately configurable.

The VMS console shall provide a visual location for cameras that have recently been viewed by the operator. Cameras displayed in this location shall be represented by a live view image from the camera at reduced frame rate for easy reference.

It shall be possible to minimize each individual element of the Surveillance Console to maximize the use of the screen for video display.

The VMS shall support Snapshot feature, whereby on the click of a button operator shall captures the current frame of video and saves it as a bitmap image. This shall be available when viewing both live video and recorded video.

The VMS shall support Sequencing in Views, whereby the pre-sets of PTZ cameras as well as fixed cameras are cycled on a timed basis, within a single view or within the view port of a multiple camera view.

The VMS shall support Image Blocking preventing unauthorized operators from viewing live or recorded video when a specific class of operator takes control of a camera, thus helping to prevent potential collaboration between operators and suspects.

g. Mobile Client for Video

The VMS shall have integrated Mobile clients to view the cameras from the Smart mobile phones. The mobile application shall support iOS/ Android mobile OS.

Video shall be streamed at reduced frame rates and increased compression in case of insufficient network bandwidth. When sufficient network bandwidth becomes available video quality is automatically restored.

Mobile client shall have a navigation pane to select the cameras, locations and groups of cameras.

Mobile client shall support min concurrent camera views in Smartphone device and concurrent camera views in tablet devices.

PTZ function shall be available in mobile app for the PTZ cameras. Selection of pre-sets in PTZ camera shall also be available in mobile client

Mobile client shall display real time frame delivery statistics for a video stream as an overlay on the video.

h. Bi-Directional Audio Support

The VMS shall support Bi-directional Audio providing a simple and inexpensive IP Intercom solution utilizing the existing network camera.

i. Edge Recording and Backfill

The VMS shall support edge recording of video on SD card inside the camera in case of network connectivity between camera and VMS is down. The VMS shall support restoration of edge recorded video in the VMS storage once the network connectivity between camera and VMS is up.

j. Digitally Signed Export of Camera Videos

The VMS shall support export of video for evidentiary purposes. It shall be possible to select the portion of video required and export only that portion in Windows Media Format and Native Format.

The VMS must support all exported recordings and exported audit logs to be digitally signed to prove authentication (origin of the recording and audit log) and integrity (exported recording and audit log have not been altered or tampered with).

The VMS system shall provide a default digital certificate for signing the exported recordings and audit logs. Customization shall also be provided to allow for the user to supply his/her own digital certificate.

k. Camera Temper Detection Feature

The VMS shall support temper detection for the connected cameras. Temper detection shall include changed field view, camera blurred and camera blinded.

l. PTZ Camera Control

The VMS shall support Area configuration to allow users to view specified cameras only.

The VMS shall support Control Level determining if a user is allowed to operate the PTZ controls for a camera.

The VMS shall support Control Reservation Period allowing if a particular user has controlled the camera no other user can control the camera until this reservation period has expired. Users with a higher security level shall be able to take control of the camera at any time.

m. Recording and Archiving of Camera Videos

The system has to provide sufficient storage to record all cameras for 30 days at 1080p, 25 fps, H.264 compression.

The VMS shall provide the ability to automatically archive all recordings. It shall be possible to automatically archive any type of recording at a preconfigured period after the recording has completed. It shall be possible to modify the automatic archive setting for each recording individually, as required.

The VMS shall support continuous background recording, scheduled recording, event activated recording and user activated recording for all connected cameras.

n. Search and Playback of recorded Videos

The VMS shall provide a simple search for all video recorded. The user selects the time indicator which shows a calendar and time line. The user selects the required search period. Once the time criterion is entered, the “search” is selected. Video recorded during the selected period will be returned by the search.

The VMS shall provide an advanced search of recorded video. The search shall be based on recording time, camera and recording details. Wildcards shall be accepted for the Point ID, description, area, priority and value for alarm/event activated recordings.

o. Intelligent Video Analytics

The VMS shall have an integrated Intelligent Video Analytics system from same or other OEM.

Events from the Intelligent Video Analytics system shall be passed back to the VMS to start a recording and generate an alarm of configurable priority.

The Video Analytics System shall have following algorithms-

- person entered/exited restricted area
- person loitering in restricted area
- people converged or crowd gathering

- person trespassing - tripwire
- vehicle entered/exited restricted area
- vehicle parked in restricted area
- Video signal lost
- Camera defocused/ blurred
- Camera blinded
- Camera scene changed
- object left unattended
- object removed/ possible theft

p. Digital Zoom and Image Enhancement on live video

The VMS shall support the ability to digitally zoom into an area of the image as well as provide the ability to enhance the image viewed by adjusting the levels of brightness, contrast, noise levels and sharpness for both live and recorded video.

q. Alarm Module

The VMS shall have integrated Alarm Module for video system and analytics alarms.

The Alarm module shall have Alarm and Event summary with Video Clip attached.

The Alarm module shall provide Audio Alert in different audio tones for Low, High and Urgent priority alarms

The Alarm module shall provide Alert in different colours for Low, High and Urgent priority alarms

The VMS shall have the feature to pop-up video from the camera on a dedicated alarm monitor in case of an alarm is generated in that camera. The cameras will be queued in sequence in case of multiple alarms till they are acknowledged by the operator.

The system shall have feature to send SMS alerts to predefined users in case of predefined priority alerts.

r. Diagnostic Module

The VMS shall provide diagnostic modules to assist with system health assessments and collection of diagnostic information.

The Diagnostics applications shall provide a unified user interface for running tests, recording system activity, collecting diagnostic information and viewing system log files.

It shall be possible to collect diagnostic information on all components of the VMS application including Database Servers, Recording Servers, Clients and network activities.

s. Enterprise Command Wall at Central Command Station:

The Video management System shall include an Enterprise Command Wall with touch interface at the Central Command Station. The Command Wall shall be a high definition multi touch screen with a minimum size of 60 inches.

The Enterprise Command Wall shall be used as a central resource for the review and discussion of operating activities and incident management.

The Enterprise Command Wall shall provide seamless integration with CCTV, Access Control, Fire

Alarm System and Perimeter Intrusion Detection System.

The Enterprise Command Wall shall have following features:

- Map navigation using multi-touch gestures - Pinch to zoom, Drag to pan
- Single touch navigation to area of interest
- Progressive Disclosure of map elements such as cameras, Access points and Sensor points.
- Contextual Incident notifications
- View incidents on map elements

- Contextual alarm notifications
- Alarms on map elements
- Enhanced Ontology to support Security and Fire
- Live video embedded in map, Camera Control (PTZ) using touch gestures, Video playback /Play/Pause /Fast forward/Rewind/Instant 30s rewind Controls

The Enterprise Command Wall shall be capable of all sub-systems at a single user interface to improve situational awareness and responsiveness particularly in abnormal situations.

t. Incident Management System:

The VMS shall have an integrated Alarms, Incident Management and Reporting module. The Incident Management System must have following features as minimum-

- Automatic creation of an incident based on a system detected condition
- Manual creation of incident
- Scheduled Incidents
- Customized Incident summary View
- Incident ownership and handover
- Execution of corresponding Standard Operating Procedures (SOPs)
- Authorized/Automated steps
- Import/Export of Standard Operating Procedures (SOPs)
- SOP Design User Interface
- Chronological comments
- Escalation- Manual/Time based
- Auto acknowledge of associated alarm
- Live video and Map orchestration
- Incident compliance Report
- Incident Summary Report

u. SPECIFICATION

1/2" colour camera of CMOS solid-state type

Resolution : at least 752 pixels (h) x 582 pixels (v)

Sensitivity : 0.5 lux for distinguishable picture, minimum

Geometric distortion : none (Lag and image distortion shall be minimized Automatic white balance)

Signal to noise : 5 (6 dB minimum)

Light range : 1 min with auto-iris lenses, Auto black in reference to the

darkest picture element Ten-digit insert text for camera recognition (minimum) 625 lines and 50 fields per second

v. SYNCHRONISATION:

- Line - Lock: Synchronises the camera to the power line zero crossing, for a roll-free vertical interval switching
- Genlock: Accepts composite video, composite sync, or H & V drivers for genlock operation
- Crystal – Lock: Internal crystal reference with full genlock capabilities to allow master synchronisation Lenses shall be with "C"-mounts.

VIDEO OUTPUT SIGNALS:

Standard video signal: - 1 Vpp at 75 Ohm asymmetrical

Two wires output: - 2 Vpp at 150 Ohm symmetrical

**CAMERA LENSES**

Lenses shall be with "C"-mounts.

Lenses for cameras mounted outside the tunnel: f/1.61 minimum range 11 - 100 mm or as approved

Lens for cameras inside the tunnel: f/1.4, 16 mm or as approved

The zoom shall be motor driven and remote-controlled. The lens shall have auto iris.

All other technical specifications as those of the camera are also valid for the lenses.

**CAMERA HOUSING**

The waterproof camera housing shall consist of highly corrosion resistant stainless-steel material No.l.4404.

System of protection:- IP 67, IK 10

Input voltage:- 240 V, 50 Hz

Window heater: - 20 W, thermostat controlled, overheat limiting thermostat A sun shield for all cameras outside the tunnel shall be provided.

**CAMERA MOUNTING BRACKET**

The camera mounting brackets shall be used for mounting the cameras on the tunnel wall or on a column in the free field area. Also, the dome cameras shall be installed with this camera mounting bracket.

The material of the mounting bracket shall be of stainless steel with painting and shall be resistant against all environmental conditions. All fixing bolts shall be made of stainless-steel No. 1.4404. Connection cables between each camera head assembly and the corresponding camera distribution box shall be fed down the pole internally.

**10. Dome Camera**

The dome cameras in the free field area shall monitor the portal areas of the Tunnel. The dome cameras shall be equipped with additional pan, tilt and zoom function (PTZ).

The electrical connection to the mounting shall be of waterproof fixed plug type.

The mechanism of the pan, tilt and zoom function shall not allow more than 1/3° free movement

(play) in any direction locked, a pan movement of 0° to 360° in horizontal plane and a tilt movement of +I- 90° minimum. Velocities of movement shall be approximately 6°/sec. for pan and approximately 3°/sec. for tilt.

The housing of the pan/tilt-system shall be waterproof; system of protection: IP 67, IK 10.

The exact location of the cameras, in the free field area shall be defined by the Concessionaire in accordance with the Client on-site, depending on the landscape and the final prevailing conditions. It shall be guaranteed that, with the placement of the camera, the whole portal is visible.

The dome cameras shall be installed on therefore foreseen camera columns.

**11. Optical Video and Data Transmission**

The video signal of each camera shall be transmitted via an own fibre of a 9/125 □m single mode optical-fibre cable at the range of 1320 or 1550 nm from the camera to the Control Room.

The second fibre of this cable shall be used for data transmission (camera error, etc.). The third fibre shall be used for the control of the pan/tilt/zoom unit. The fourth fibre shall be spare.

Appropriate transmitters and receivers changing electrical video signals into optical signals and vice versa shall be provided.

Noise clearance: - at least 50 dB

Video signal: - FBAS 1 Vss at 75 Ohms (Functional behaviour assessment surveillance)

**12. Optical Video Transmission Fixed Cameras**

The video signal of each camera shall be transmitted via an own fibre of a 9/125 µm single mode.

fibre-optic cable at the range of 1320 or 1550 nm from the camera to the multiplexer. A second fibre of this cable shall be used for data transmission (camera error/ etc.) Appropriate transmitters and receivers changing electrical video signals into optical signals and vice versa shall be provided.

Noise clearance: - at least 50 dB

Video signal: - FBAS 1 Vss at 75 Ohms

## 13. Camera Distribution Box

Each camera shall be connected with an own camera distribution box containing the necessary hardware to interface the power supply, control signals and the video signal as well as the electro-optical converter needed for transmission.

For dome cameras in the free field area, the distribution box also shall drive the pan/tilt facility and the motor zoom as ordered from the remote control.

Suitable terminations shall be provided for incoming and outgoing cables. The camera distribution boxes shall have a degree of protection of IP 67and all doors of the camera distribution boxes shall be protected by a suitable lock. Preferably all boxes shall be of identical size. If this is not possible due to physical constraint in the tunnel, not more than two standard box sizes shall be used, one for using inside the tunnel and one for the outside cameras. Construction details of the boxes and type of the lock shall be subject to the approval of the engineer. Details shall form part of this submission.

Protection devices of an approved design shall be connected to each signal line at each camera distribution box in such a way, that no damage occurs under fault conditions. The Concessionaire shall state the surge protection capabilities of these limiting devices. These devices shall protect the equipment from main voltage (250 V) across a pair of signal lines or between a wire and ground and surges induced on the lines due to lightning etc.

Each outside camera distribution box shall be placed at a suitable point in that way, that the movements of the associated camera are clearly visible and can be easily checked. So, the best mounting point would be the camera column / pole itself.

Camera distribution boxes for tunnel cameras shall be mounted near to the camera above the clear open space on the tunnel wall. The Concessionaire shall state the maximum distance that is allowed between the camera and the camera distribution box.

Were column I pole-mounted camera distribution boxes are used, all cables to the cabinet shall be laid inside of the column I pole and further in conduits (in ground). The cables shall be easily maintain-able from ground.

## 14. Video Recording Unit

The Video Recording Unit shall be dimensioned for all cameras. The Video picture Recording Unit

consists of:

- Recording unit
- Storage
- Interface to Video-LAN

The analogue digital signal from the camera shall be transmitted to the camera distribution box / which shall convert the electrical signal into optical signal. Through optical fibre cable the video signal shall be transmitted to the multiplexer, which shall be situated in the Niches. From the Multiplexers, the video signals shall be sent via an optical fibre cable ring to the Control Room Building. In the Control Room Building the signals shall be de-multiplexed and digitized by the Digital Video Codecs. After the video signals were digitized, they shall be stored on hard disks (RAID Units).

## 15. Video Detection Unit

The execution of the Video Detection Units shall be made with built in frames in the distribution cabinets.

The system must be able to detect pedestrians, and vehicles which are entering the tunnel.

The Video Detection Unit shall be able to evaluate the video images also in case of a reduced

illuminance and reduced contrast because of dust in the tunnel, etc.

a. <u>DETECTING AT PORTALS</u>

For detecting in the free field areas; one detection camera at each portal side shall be installed. With the Video Detection Unit it shall be possible to differentiate between pedestrians and vehicles. If a vehicle passes the tunnel, no alarm shall be triggered. If a human or a vehicle will enter the tunnel, an alarm shall be activated in the Control Centre and equipment Room . The CCTV images next to the alarm place shall be displayed on the CCTV alarm screens.

The detection of humans- never mind of standing or moving -shall be realized within 20 seconds.

b. DETECTING INSIDE TUNNEL:

For detecting purposes inside the tunnel tube, one camera each 150 m shall be installed (TV. D8, TV. D16, etc.). Those cameras shall have additionally to the common monitoring function, the functionality of detecting. If a vehicle passes the tunnel, no alarm shall be triggered.

The selected cameras inside the tunnel tube shall detect the velocity of the vehicles. The velocity measuring of the velocity shall be detected in a span between 5 and 100 km/h. Further if the velocity of the vehicle falls below an adjustable threshold value, information of the vehicle velocity must be handed over to SCADA and further to the Tunnel Ventilation System.

c. SOFTWARE & FUNCTIONS: -

- Suitable software for the control of the whole CCTV System, including picture switchboard and recording unit.
- Software to show every selected picture (Live pictures or pictures from the storage).
- Administration and configuration of the video network (Video-LAN)
- Tools for burning a CD and print the video pictures

d. INFRARED LED ILLUMINATORS SEMI-COVERT

Electrical

| | |
|---|---|
| Input Voltage | 12 VDC ±10%;<br>24 VAC ±10% |
| Power Consumption | 12 W maximum |
| Power Cord | 2.5 m 12 or 24 VAC/DC |

General

| | |
|---|---|
| Wavelength | 850 nm/940 nm |
| Average Life (Lamp) | 10 years |
| Construction | Aluminum body, stainless steel bracket,<br>polycarbonate cover |
| Finish | Gray polyester powder coat |
| Operating Temperature | –40° to 50°C (–40° to 122°F) |
| Storage Temperature | –50° to 75°C (–58° to 167°F) |
| Weight | Unit Shipping<br>0.65 kg (1.40 lb) 0.80 kg (1.70 lb) |

Mechanical

| | |
|---|---|
| Bracket Mounting | 6.50 mm (0.25 in) hole diameter |

| | |
|---|---|
| Bracket Adjustment | 2, 4 mm AF hex (M6 hex button head) |

e. CERTIFICATIONS / PATENTS

• CE

• FCC, Class B

• UL/CUL Listed

• Meets IP66 / IP67 rating (environmental) and IK9 / IK10 (vandal resistant)

f. SUPPLIED ACCESSORIES

Units are factory-installed with a 35 x 10° Interchangeable Diffuser System (IDS); an additional 60 x 25° IDS is supplied.

g. RECOMMENDED ACCESSORIES

| | |
|---|---|
| RC - LED | Remote control for IR850, IR940, or WLED illuminators |
| LENSPKS - LED | Wide angle lens pack (80° and 120°) for IR850S-65, IR940S-30, or WLEDS-50 |
| LBKT- LED | Mounting bracket for installing IR850, IR940, or WLED illuminators on walls or flat surfaces |

h. INTEGRATED COMMAND AND CONTROL

| | |
|---|---|
| Standard | Built-in photocell for automatic on operation; LED Status Feedback System provides status on performance of the unit; photocell following output |
| Advanced | Accessed with remote control:<br>– Power adjust from 20 to 100%<br>– Photocell sensitivity adjust<br>– Timer function (up to 30 minutes)<br>– Telemetry control or remote dimming<br>– LED Status Feedback System on/off<br>– Restore factory default settings |

**16. Camera Column**

The column shall be made of galvanized steel. Height above ground: 5 m

The exact location of the cameras, out of the tunnel, in the free field area shall be defined by the

Concessionaire in full accordance with the Client on-site, depending on the landscape and the final

prevailing conditions. It shall be guaranteed, that with the placement of the camera, the whole portal is visible. The cabling shall run in the camera column. Furthermore, the columns shall have a lockable opening into the interior part of the column for cable installations. The opening shall be in a height, which is good reachable for the installation and maintenance people.

The column shall be fixed in foundations (the costs therefore shall be calculated into the price of the column). The

column shall be connected to the earthing system by the Concessionaire of Telecommunication.

**Table 10: TECHNICAL DATASHEET FOR CCTV SURVEILLANCE SYSTEM (BULLET CAMERA)**

| Sr. No. | Parameters | Technical Specifications |
|---|---|---|
| **3 MEGA PIXEL FIXED BOX CAMERA INSIDE THE TUNNEL** | | |
| 1 | Image Sensor | 1/2.8" Progressive CMOS |
| 2 | Resolution | 2048 x 1536 |
| 3 | Minimum Illumination | Colour- 0.5 Lux @ 30IRE, Black & White- 0.05 Lux @ IRE |
| 4 | Lens | 2.7mm to 12m Motorized Focus/Zoom Lens, F1.4 |
| 5 | Back Light Compensation | BLC/ HLC |
| 6 | Motion Detection | On/ Off |
| 7 | Wide Dynamic Range | True WDR; 120 dB |
| 8 | Day/ Night | Auto/ Color/ BW, True Day/Night with ICR |
| 9 | Shutter Speed | 1/10 to 1/10000 Sec |
| 10 | Noise Reduction | 3D Noise Reduction (3DNR) |
| 11 | Signal to Noise Ratio | >=50dB, Back Light compensation ON/OFF selectable |
| 12 | IR Illumination | Built-in IR LEDs with up to 100m illumination |
| 13 | Privacy Mask | Mask up to 4 areas of a scene from view and record |
| 14 | Video Compression | H.264, MJPEG |
| 15 | Video Streams | Primary Stream: 1080p/ 720p/ D1 @ 25/30 fps<br>Second Stream: D1/CIF @ 25/30 fps<br>Third Stream: 720p/D1/CIF @ 25/30 fps |
| 16 | Network Protocols | IPv4/IPv6, HTTP, HTTPS, TCP/IP, UDP, UPnP, ICMP, IGMP, RTSP, RTP, SMTP, NTP, DHCP, DNS, PPPOE, DDNS, FTP, QOS, SNMP v2c/v3, LDAP (Client), NFS, RTCP, Bonjour |
| 17 | Security | User account and password protection |
| 18 | Supported open Protocol | ONVIF Profile S & G |

| | | |
|---|---|---|
| 19 | Onboard Storage | Up to 128 GB Micro SD Card |
| 20 | Onboard Recording Type | Event trigger recording<br>Continuous and scheduled recording<br>Automatic recording when network fails |
| 21 | Event | Motion Detection, Video Tamper, Network Disconnection |
| 22 | Event Notification | Record in SD Card/ FTP, Relay Output, Snapshot |
| 23 | Alarm Input/ Output | 2 Inputs, 1 Output |
| 24 | Power Source | 12VDC ±10%, 24VAC ±10% 50Hz, PoE 1EEE 802.3af |
| 25 | Operating Temperature | -30°C to 60°C |
| 26 | Operating Humidity | 20 to 80% RH (non-condensing) |
| 27 | Vandal Resistant | IK10 |
| 28 | Ingress Protection | IP67 |
| 29 | Regulatory | • CE – EN 55022 (Class A), EN 50130-4, EN 60950-1<br>• UL and cUL Listed – UL 60950-1, CAN/CSA – C22.2 No. 60950-1-07<br>FCC (Class-A) – 47 CFR Part 15 |

**Table 11: TECHNICAL DATASHEET FOR OUTDOOR PTZ CAMERA AT TUNNEL PORTALS**

| Sr. No | Specification | Parameter |
|---|---|---|
| **30X, 2Mpx High speed PTZ Dome Camera** | | |
| 1 | Image sensor | 1/2.8-inch CMOS Sensor |
| 2 | Resolution | 1920 X 1080 @ 60FPS |
| 3 | Dynamic Range | 130db |
| 4 | White balance Range | 2,500° to 8,000°K |
| 5 | Signal to Noise Ratio | 50dB |
| 6 | Electronic Shutter Range | 1 ~ 1/10,000 sec |
| 7 | Minimum Illumination | Color (200 ms) 0.08 lux ; Mono (200 ms) 0.015 lux |

| | | |
|---|---|---|
| 8 | Imaging Technology | – Anti-Bloom Technology<br>– 3D Noise Filtering<br>– Enhanced Tone Mapping |
| 9 | Lens | 4.3 mm (wide) ~ 129.0 mm (tele) |
| 10 | Optical Zoom | 30X |
| 11 | Digital Zoom | 12X |
| 12 | Horizontal Angle of View | 55.4° (wide) ~ 2.9° (tele) |
| 13 | Iris Control | Auto iris |
| 14 | Active Noise Filtering | Yes |
| 15 | Presets | Min 256 preset |
| 16 | Tours | 16 |
| 17 | Preset Accuracy | Pan ±0.1°; Tilt ±0.05° |
| 18 | Auto flip feature | Yes |
| 19 | FPS | Camera should support 1920 X 1080 @ 60 fps |
| 20 | Video Streams | Both Primary and Secondary Stream at 1920 X 1080 @30FPS |
| 21 | Audio | Embedded with stream 1 and stream 2<br>G.711 A-law/G.711 U-law |
| 22 | Supported Protocols | TCP/IP, UDP/IP (Unicast, Multicast IGMP), UPnP, DNS, DHCP, RTP, RTSP, NTP, IPv4, IPv6, SNMP v2c/v3, QOS, HTTP, HTTPS, LDAP (client), SSH, SSL, SMTP, FTP, and 802.1x (EAP), GB28181 |
| 23 | Built in Analytics | Object Counting , Abandoned object , Stopped Vehicle , Loitering Detection, Intrusion Detection , Wrong Direction , Camera sabotage . |
| 24 | Local Storage | Up to 32GB onboard Micro SD, SDHC Compatible |
| 25 | Analytics | Motion Detection and Camera Sabotage |
| 26 | Pan Movement | 360° continuous pan rotation |
| 27 | Tilt Movement | +1° to –90° |
| 28 | Preset Speed | Pan 430°/sec; Tilt 200°/sec |
| 29 | Variable Manual Speed | Pan 0.1°/sec to 100°/sec<br>Tilt 0.1°/sec to 50°/sec |

| | | |
|---|---|---|
| 30 | Ports | RJ-45 connector for 100Base-TX; Auto MDI/MDI-X;<br>Auto-negotiate/manual setting |
| 31 | Alarms | 1 X inputs and 1 X output |
| 32 | Input Power | HPOE and 24 VAC and 24VDC; 50 VA |
| 33 | Operating Temperature | -40 to 50deg C |
| 34 | Operating Humidity | 10% to 100% (noncondensing) |
| 35 | Housing | Aluminum Housing with Polycarbonate Bubble |
| 36 | Environmental Protection | Ingress for Water & Dust - IP66 / IP67 or higher |
| 37 | Vandal Proof Certification | IK10 or higher |
| 38 | Certificates | CE & FCC & UL CUL |
| 39 | ONVIF Compliant | ONVIF Profile S and Profile G conformant |

### 7.2.15 Tunnel Radio

This covers the whole Tunnel Radio equipment of all the required equipment, material, accessories, and all labour.

The Concessionaire shall provide a Tunnel Radio System, which guarantees a complete radio capability in the whole tunnel (even in the Accesses if any). Transmitter and receiver frequencies are required for road and emergency staff.

The realization of those shall be calculated into the prices of the Tunnel Radio System.

If any coordination is necessary, all coordination (even with the local fire brigade, rescue service, police, military, etc.) shall be included in the prices of the Tunnel Radio System.

Connection to control centre shall be (made by Concessionaire of E & M).

The Signals of the Tunnel Radio System shall be transmitted from the LF-connecting network to the telecontrol system with TCP / IP cabling.

The whole Tunnel Radio System shall be as uniform as possible. Further on devices, which are easily to expand, and change shall be used.

The different parts of the Tunnels Radio System shall be arranged by easy changeable, pluggable units with very accessible operator's controls. Also, those parts of the radio system, which shall be maintained, shall be very accessible.

The required values of the tunnel radio system shall be kept, even by these environmental conditions:

- Relative air humidity 100 % till -20°C
- Ambient temperature by parts of the plant in heated rooms of 0°C - + 40°C
- Ambient temperature by parts of the plant, which are located elsewhere from -20°C -+50°C.
- Power supply voltage with a range of -15% - +10%.
- System frequency of 50 Hz ± 2 %

**1. Scope of Work**

- Radio Service and Channels
- Amplifier

- Tunnel Antenna – Leaky Feeder Cable
- Antenna Column
- Free Field Antennas
- Cabling
- Desktop Station

**2. Technical Specifications**

**Functionality of Tunnel Radio System**

a. The operation stations of the Tunnel Radio System shall be provided in the control centre and in the equipment room buildings. The Tunnel Radio System also shall be integrated in the telecontrol system (SCADA).

b. The Tunnel Radio System shall provide an uninterruptable radio connection to the headquarters and operation centres for all vehicles and handheld device of the tunnel operator's staff, emergency staff and vehicles, which passes the tunnel.

c. The communication of all channels in the tunnel shall be independently, simultaneous and failure free.

d. No disturbing interferences shall occur at the tunnel portals; there are crossovers from the free field radio area to the tunnel radio area.

e. The radio signals of the free field area shall be handed over with the free field antennas and shall be transferred to the radio central unit at the equipment Room control room.

f. The Concessionaire shall measure the best location for the antenna column. The measurement protocol shall be handed over to the client. In accordance with the client, and the measurement, the exact location of the radio column shall be determined.

g. In case of breakage, malfunction information shall be indicated for every channel. This malfunction information shall be available in the tunnel radio cabinets as potential free two-way contacts. Also malfunction information of the tunnel antenna monitoring, and the malfunctions of their power supply units shall be indicated at SCADA.

h. The Tunnel antenna system shall be wide band system; for the frequencies between 68 MHz and 470 MHz. The channels may have any frequencies, which are in this frequency band.

i. An enlarging of additional channels in the Tunnel Radio System shall be easily, and without any adjusting operations to do. Also, a changing of frequencies, at already existing channels in the system, may be done as easily as the enlargement. The changing shall be done without intervention of installed transmitting system in the tunnel. Only in the Equipment Room / control room the equipment shall be adjustable. The changing of frequencies shall be able with common maintenance tools and measuring devices.

j. The transmitting of the individual channels must not be influenced by each other.

k. The antennas in the free field area shall be situated on the column. It shall be a tubular column and situated in location, depending on the best receiving frequencies. These antennas shall be directional antennas, which shall be directed to the respective bases and relay stations.

l. To avoid a coupling between the free field antennas and the tunnel antenna, a decoupling, which is as high as possible (about 140db), shall be realized. if the decoupling of the individual channels is not enough, additional methods shall take place, to guarantee a fully functional Radio System. By the overtaking of the radio system by the client, the definitely decoupling of the radio system shall be verified metrological.

m. The Tunnel Radio System shall work automatically and without external support.

n. The Concessionaire shall calculate the values of the system.

o. In the tunnel the transmitting probability of the radio signals shall be 98%.

p. The radio devices of the system shall have transmitted power between 1 W and 10 W. The mobile radio devices shall have the small transmitting power, as well, as a mini flexible antenna with a negative antenna gain.

q. All parts of the radio system shall be supplied redundantly. The power supply units shall be supplied by two separated voltages (Normal supply and UPS), and separately protected be miniature circuit breakers. A malfunction of a power supply shall be indicated.

r. Not even parts of radio system shall be supplied via HF – cables.

s. All housing of devices and distributors shall be connected to the earthing system (by the Concessionaire of tele communication).

**3. Radio Service and Channels**

The number of channels is determined, and their frequencies shall be determined in accordance with the Indian standards, client and the local requirements.

The equipment of the tunnel Radio System in the tunnel tube shall be placed in the (control) cabinets of the EM niches. The Concessionaire shall avoid a collision with other equipment, placed in the EM niches.

**a. IMPEDANCE OF TUNNEL RADIO SYSTEM**

All components of the radio system in the free field area shall be executed 50 Ohm technology.

**b. SURVEILLANCE OF CABLING**

An appropriate surveillance system shall be erected (e.g. (audible) pilot signal). The signals shall be transferred as potential free contacts to tunnels control system.

The surveillance system shall contain at least following components:

- HF components for transmitting and receiving equipment, pilot signals, monitoring of cabling, inclusive all evaluation units
- Filter, equalizer, pre-amplifier, overvoltage protectors, test sockets, etc.
- Cable joints, system switches, inclusive cabling and terminals to the HF-connecting networks, and transferring of the message.

Desktop stations shall be erected in the Control Centre and in the equipment Room. They are for enabling the tunnel operators speaking into the Tunnel Radio System. Also, the possibility to play messages shall be given at the desktop stations.

The beginning and ending of a message shall be indicated.

**c. MEASUREMENT OF TUNNEL RADIO SYSTEM**

- Design – Measurement:

Before the beginning of installing the tunnel radio system, the receiving relations at the tunnel portal / control room

- Takeover – measurement:

After finishing of installation work of the Tunnel Radio System, measurements shall be taken to guarantee the functionality on one hand, and the compliance of all standards on the other hand.

The Concessionaire shall hand over a paper original as well as an electronic copy of the measurements.

**4. Details of Tunnel Radio System**

**a. MALFUNCTION INFORMATION**

The malfunction information shall be potential free contacts and shall be available directly at the distributors. This malfunction information is necessary:

- General malfunction radio
- Malfunction optical transducer
- Malfunction for each channel
- Malfunction for each part of the leaky feeder cable
- Malfunction of every wide band amplifier (ON / OFF)
- Malfunction of connection to control center
- Malfunction of complete tunnel radio system

If more malfunction information is required for full operation, they shall be calculated in the price of the Tunnel Radio System.

A monitoring of HF free field transmitters shall be provided. If one transmitter occupies a frequency for a long time, the connection will be disconnected automatically after 10 min.

**b. TECHNICAL REQUIREMENTS**

The devices of radio system shall not cause a sound pressure level in the working rooms, which is more than 50db(A).

All equipment of the Tunnel Radio System shall guarantee a simultaneous and disturbing free operation. It shall be verified, if the foreseen frequencies are free of intermodulation among themselves. If they are not free of it, corresponding actions shall take place.

In case of power loss, the device of the radio system shall not be damaged. If the power supply returns, the radio plant shall start and work automatically and self- acting again.

**c. OTHER REQUIREMENTS**

i. Measuring Sockets:

Measuring sockets with defined coupling shall be installed at the terminals of the tunnel antennas. Although a damping of the out-coupling is required, so that all in and output signals can be monitored by common measurement devices.

ii. Measurement Technique:

The Concessionaire shall deliver interface adapters and interface cables as well as according maintenance software inclusive manuals.

iii. Coaxial Interconnection:

- The HF-Coaxial interconnections shall correspond internally to the IEC-Standard types BNC, N and SMA.
- Externally they shall correspond to IEC- Standard types BNC, N.3.5/9.5 and 4.1/9.5 and 7/16 and 3.5/12.
- If the Concessionaire uses other types, corresponding measuring tools shall be delivered.
- Additionally, the HF-interconnections of the leaky feeder and coaxial transport cables shall be extensively silvered inside (at the contact areas) and have a protection against oxidation outside.
- All coaxial interconnections which are stressed by weather or washing solutions, shall be protected against these influences by shrinkable tubes or else.
- if there are shared connections, multi- terminals shall be used. if litz- wires shall be connected, wire end ferrules shall be used.

**d. CONTROLLING**

The UPS- supplied parts of the tunnels radio equipment shall work with zero-signal current principal. Other controlling equipment shall only work with this principle, if no substantiated reasons are against it. Controlling equipment, which may cause a transition-signal, shall work with the principle of operating current.

potential free contacts are necessary for controlling. They shall be dimensioned for a capability of at least 0.2 A and 50 VDC.

The tunnel antenna shall not be used for transmitting of controlling signals.

**e. LOW FREQUENCY SIGNALS**

Standard level: 6 dBm at 600 ohms (±0.5dB)

(A) Output signals of radio receivers:

The standard level shall be reached at every interface with a modular frequency of 1 kHz and this hub:

- 1.62 kHz with phase modulation (PM)
- 3.0 kHz with frequency modulation (FM)

(B) INPUT SIGNALS at every interface:

With a frequency of 1 kHz and the defined standard level of the frequency hub at each transmitter:

- 1.62 kHz with phase modulation (PM)
- 3.0 kHz with frequency modulation (FM)

(C) The type of modulation shall be the same at all devices of the radio service. The input signals at every interface are:

- Frequency response for outgoing signals: The tolerance scheme according to CCITT / 5 shall be used.
- Noise Voltage: if there are no. LF - signals on the cable, the noise voltage shall be less than 46 dBm.
- Equalization of wiring: The plant shall be able to equalize wirings up to a 10km, so that a tolerance according to CCITT / 5 at the frequency response may be kept.
- Feedback at 4 wire wiring: An incoming signal with a level of 6 dBm and a frequency of 1 kHz shall not cause a signal in the outgoing wiring with a level higher than 46 dBm.

**f. PRECAUTIONS FOR FUNCTIONAL TEST**

For measurements of frequency and levelling at the high and low frequency parts of the radio devices, the Concessionaire shall provide measuring and control sockets. It shall be possible, to take the measurements during operation.

At the control outputs, the values of the corresponding equalizations shall be indicated.

**g. GENERAL MECHANIC STRUCTURE**

All switches, pilot lamps, control sockets and other operator's controls shall be very accessible after opening of the distributor's door (and) the swing frame in the distributors.

The lettering of the radio plant shall be undetachable and unmistakable. The indication also shall be in accordance with the documentations.

The equipment, which is necessary for signal conditioning, shall be situated in the maintenance Niches and Cabinets in the tunnel tube and in the equipment room. They shall be located in cabinets.

**5. Details and Specifications of Devices**

**a. FREE FIELD RADIO SYSTEM**

The complete transmitting and receiving devices of the free field area radio system shall have an adjustable output power (1W -10 W). The minimum responsivity shall be 0.4µV for 20 dB S+N / N and measured with CCITT filter.

The free field area radio shall be designed in that way, that no disturbance may occur between the tunnel radio system and the free field area radio system.

The transmitting and receiving device shall be delivered with all cable coupling and connectors.

The device shall be situated in distributors in the equipment room building.

**b. TUNNEL RADIO TRANSMITTER**

The complete transmitting device shall have an output power, which guarantees the required minimum responsivity in the tunnel.

The Concessionaire shall deliver the transmitting device shall including all cable couplings and connectors.

**c. TUNNEL RADIO RECEIVER**

The exact size of the frequency band depends on the used system (which shall be defined in accordance with the client). The radio receiving device shall support the services for those frequency bands.

The receiving device shall be delivered with all cable couplings and connectors.

**d. COMBINER / DIVIDER**

The interconnection of all signals to and from the tunnel antenna system shall occur in a corresponding connecting network with filters, directional couplers, isolators, separating filters, etc.

The changes of the frequencies at the connecting network shall be easily to do.

**e. COMBINER TUNNEL TRANSMITTING PLANT**

All Tunnel transmitters shall be interconnected by a combiner, so that the occurring intermodulation products are at least 60dB beneath the amplitude of the smallest useful-carrier. If the intermodulation signal meets a fundamental frequency of a tunnel receiver, this signal even not shall make the tunnel receivers operating.

Simultaneous operation of all radio service shall occur without influencing of each other.

The combiner shall be modular and easy to maintain and service. All tunnel radio transmitters of the radio plant shall be able to be combined and supplied into the radio transmitting system. This shall be able for all channels.

**f. COMBINER / DIVIDER TUNNEL RECEIVING PLANT**

The signals, which were received by the tunnel antennas, shall be divided by suitable actions to the responding receivers.

Intermodulation problems and disturbing interferences shall be avoided.

The divider shall be modular and easy to maintain. All HF-signals of the radio transmitting system plant shall be able for spreading them to the tunnel radio transmitters.

All necessary equipment and material for installing the combiners and dividers shall be included in the price of the tunnel radio system.

**g. LOW FREQUENCY PREPARATION**

The equipment for low Frequency Preparation shall be equipped as approved.

These preparations include all necessary functions and equipment, which are required for faultless operation / combining and dividing of LF- signals, as eg combination, dividing, amplifier, mixing amplifiers, distribution amplifier, frequency response equalization, galvanic separation, overvoltage protection, etc.

Interfaces shall be foreseen for to:

- Transmitting and receiving devices
- Talk function at the desktop station in the equipment Room and the Control Centre

All equipment, which is necessary for those functions, shall be suitable equipped for the required channels.

**h. WIDE BAND AMPLIFIER CONFIGURATIONS**

The amplifiers are for terminal the leaky feeder cable and transmitting the transmitting and receiving signals. The amplifiers shall be made with the latest wide band technology (band width 68 MHz – 470 MHz) / as applicable.

The amplifier shall not cause disturbing signals by intermodulation, combination, etc. which:

- fall below a span of 8 dB in the connection of stationary station to mobile stations (span of usable carrier to unwanted noise signal in the suable wide band of as channel).
- fall below a safe clearance of 23 dB in the connection of mobile station to stationary stations (span between usable carrier to unwanted noise signal in the usable wide band of a channel).
- are less than 20 dB smaller than the smallest usable carrier in direction of stationary mobile station and an unusable signal.

The noise factor of the amplifier shall be not more than 8 dB.

The power supply occurs with 250V / 50Hz. An energy supply via the leaky feeder cable is not allowed.

The degree of protection of the amplifier shall be IP 54. The amplifiers shall be situated in the cabinets.

**i. COUPLING UNIT**

The coupling units are for electrical disconnection of the signals of the leaky feeder cable, which were supplied from both ends of the cable. But only in case of breakage, the coupling units shall be activated.

They shall be mounted directly on the ceiling of the tunnel between the both parts of the leaky feeder cable. The coupling units shall be covered with shrinking tubes, for protecting them against the tunnel atmosphere.

A low frequency sound signal, which is produced by a cable monitoring unit, shall be injected into the leaky feeder cable.

The telecontrol system uses this sound signal as indicator for the monitored parts of the leaky feeder cable. It indicates disconnections of the parts of the leaky feeder cable.

In case of a fracture (open circuit) or short circuit of one section of the leaky feeder cable, both parts of the leaky feeder cable shall be interconnected via the coupling unit.

In the coupling units are two coaxial relays, which couples the two sections of the leaky feeder cable. With this method also in the immediate area of the location of breakage, a radio operation shall be possible. The cable monitoring unit generates the malfunction information of the corresponding segment.

### j. HIGH FREQUENCY OPTOELECTRIC CONVERTER

HF opto electric converter, depending on the requirements, are used as transmitter or receiver. All equipment which is necessary for transmitting / receiving shall be included in the price of the Tunnel Radio System.

The HF optoelectric converters are necessary for the low noise transferring of HF signals over single mode fibres.

The converters shall be connected by SC terminals at patch field. The converters shall be able for installing in cabinets.

Technical requirements:

- Frequency Band: 50MHz -1GHz
- Optical Fibres: E9 /125
- Potential Free Malfunction Contact

### k. DISTORTION FACTOR

The distortion factor over each feasible connection in the system shall be maximum 10%, if the HF level is high enough.

### l. SYSTEM VALUES

The Concessionaire shall calculate and measure all values of the radio system. Thereby also those frequencies, which are announced by the client, shall be proofed, if they are free of intermodulation.

If they are not free of intermodulation, the Concessionaire shall arrange corresponding actions, to guarantee an operation, free of disturbing.

If, because of physical reasons, a mixed product may not be avoided, the Concessionaire shall already point at it in the offer!

### m. LOW FREQUENCY INTERFACES

For avoiding crosstalk on the LF cables, the cables of the radio plant shall be supplied with -6 dBm maximum.

If there is no other prescription, the value of -6 dBm shall be a specified value for the handover of LF levels to foreign of feeders.

- The output level of the radio plant shall be: -6dBm at 600 Ohm (±0.5 dB)
- If Speaking into the microphone: At 1.07-1.1 Pa sound pressure and frequency of 1 kHz
- Noise Voltage: The noise voltage shall be less than -46dBm, if there are no LF signals on the cable.
- Line Attenuation: The radio plant shall be able to equalize cable lengths up to 10km, so that a frequency response with its tolerance after 1 / 5 CCITT may be kept.

### n. Equipment For Plant- Inspection

Channel processing test sockets shall be foreseen at the LF interfaces of each channel processing unit. At these sockets, the actual levels can be measured. These measurements shall be made during operation without disturbing the radio plant. For testing purpose, the ability to disconnect the LF course at the test sockets shall be given. So, it is possible, to substitute the input signal of the plant with the test signal.

At the location of the handover from the radio central unit to the tunnel antenna system, test sockets are also necessary and shall be provided by the Concessionaire. The signals from and to the tunnel antenna shall be decoupled by directional couplers. Therewith it shall be avoided, that the levels at the tunnel antenna are influenced, at the test sockets in case of a level measurement.

At the test outputs the corresponding operation levels shall be described.

The power supply of the whole radio plant shall occur with 250V, 50Hz by UPS.

For supplying the distributors of the Tunnel Radio System in the equipment Room, these voltages shall be provided: 1 x UPS and 1 x Normal supply for the test sockets.

The number of plug sockets depends on the number of devices, which shall be plugged in. These plug sockets shall

be fused with own circuit breakers.

The power shall be controlled by these criteria:

- Triggering of main fuse in tunnel radio system distributor
- Loss of internal power supply (each voltage shall get an own information signal)
- The circuit breaker of the plug sockets shall not be controlled.

All signals shall be transmitted as potential free two-way contacts to the tunnel control system.

For all parts of the radio plants (radio central unit and tunnel antenna system) which are situated at the equipment Room or EM niches / cabinets shall not be supplied by coaxial cables. Not even parts of the radio system shall be supplied by coaxial cables.

**o. OVERVOLTAGE PROTECTION**

Cables, which are coming from the free field area and run into the radio system into the tunnel or into the equipment room, shall be protected against overvoltage.

Low frequency cables shall be equipped with isolating transformers which have a voltage endurance up to 2.5 kV. This protection consists of a combined protection against longitudinal and transverse dimensioned in accordance with the respective operating voltage.

Overvoltage protection devices shall be installed by using plug connectors with suitable terminals at antenna cables in the free field area.

**6. Tunnel Antenna - Leaky Feeder Cable**

a. In the main tunnel tube, a leaky feeder cable shall be used as antenna.

b. It consists of a coaxial structure with gaps or slots in it, with a regular span in its outer conductor for radiating or receiving signals along its entire length. Those gaps / slots ensure repeating coupling and decoupling of the energy. Furthermore, the leaky feeder cable shall have a flame-retardant sheath as per IEC 332-1, 332-3/C, 754-2 and 1034.

c. The leaky feeder cable shall be executed for 50 ohm and a frequency band of 60 – 500 MHz.

d. The section of the leaky feeder cable shall be supplied with a wide band amplifier in a T- system (in the tunnel tube to the accesses) and in a L- system (from the equipment room to the tunnel portals).

e. For transmitting and receiving of the frequencies in the tunnel tube two leaky feeder cables shall be foreseen. One is for TX- signal and other one for RX -signal.

f. A disconnection of the leaky feeder cable shall not stop or interfere the operation of radio. Each amplifier of the Tunnel Radio System shall supply leaky feeders with a length of maximum 625 m to the left and right side. If the leaky feeder cables will be squeezed or pinched off, the radio connection from the amplifier to the sectioning point shall be sustained.

g. Depending on the installation site, the cable shall be mounted with cable holder, spacer, cable clamps. plain washers, and so on. The span between the fixings shall be 1.0m. Additionally to the common fixings, fire proofed cable clamps, made of stainless, shall be installed in an irregularly span (between 8 m and max.12 m).

h. The course of the leaky feeder cable shall be straight.

i. In those areas, where shotcrete is used in the tunnel, first a steel wire rope shall be fixed on the ceiling. Onto this steel wire rope the leaky feeder cables shall be fixed. Therewith the unevenness of the tunnel ceiling shall be levelled by using corresponding spacers, so that the steel wire rope runs straight. If required, the steel wire rope shall be included in the price of the leaky cable.

j. The instructions of the cable producer and the Indian standards, which accord to the installation of the leaky feeder cable shall be considered. Furthermore, actions for mechanical protection (e.g. guide roller) shall be used. It is not allowed, that the cables were pulled on the blank concrete, edges, etc.

k. The leaky feeder cable shall be mounted on the roof of the tunnel tube.

l. The leaky feeder cable, which will be used, shall be appropriate for using in tunnels and it shall operate independently of environment influences. it shall be resistant against the tunnel atmosphere (salt, temperature change and humidity), as well as mechanically and chemically stresses insensitive.

m. Terminal resistors, which are situated in the tunnel tube or accesses, shall be made moisture proof with shrink tubes. Those shrink tubes shall be coated with adhesive inside.

n. For transmitting of control signals, the leaky feeder cable shall not be used. The power supply must not run through via the leaky feeder cable.

o. The values of the cable, as line and coupling attenuation, shall be coordinated to the whole system. The functionality of the whole system shall be verified with calculations. These calculations shall be handed over to the client.

## 7. Antenna Column

All free field area antennas shall be situated on the antenna column. The height of this column shall be 25 m The column shall be fixed on a foundation and the material shall be made of galvanized steel tube. Further the antenna column shall include a safe climbing system with fall protection ladders.

### Safe Climbing System

The safe climbing system with fall protection ladders (Y-spar ladders), made of light metal which suits to the antenna column. Also a leading system for the cabling along the column shall be covered at the lower part (the first 3 m on the column from the bottom) by a lockable covering, so that a climbing or damaging of unauthorized people will be avoided. The keys for the lockable covering shall be handed over to the client. The span between the footsteps shall be 500mm. The rung spacing shall be approx. 300 mm.

The safe climbing system also shall have a top and bottom end stop.

The safe climbing system shall be erected from the foundation of column up to masthead.

Additionally, to the safe climbing system with fall protection ladders a staff protective equipment shall be delivered. This staff protective equipment shall fit to the safe climbing system. it shall include at least a safety harness and a quick adjusting manual rope grab with shock absorber. A vertical lifeline shall be connected to an anchor point.

The antenna column shall have a protection against lighting. Therefore, a lightning rod shall be provided, and the Concessionaire shall connect all metallic parts with the earthing system.

All cables along the column shall be installed by C –section rails, which are separately fixed with cable clamps. The C – section rails shall be fixed permanently with spacer in a span of 50 cm.

The location of the antenna column shall be near the equipment room / control room. The exact location depends on the results of the measurement. The Concessionaire shall deliver static calculations for the foundation, the column and the mounting structures of the column. The calculations shall be handed out to the client.

All costs, which are combined with the delivering and mounting (also for the foundation) of the column, shall be calculated into the price of the tunnel radio system. Also the total erection and the static calculations of the foundation and the antenna column shall be included in the price of the Tunnel Radio System.

## 8. Free Field Antennas

Directional antennas for the corresponding frequency band shall be provided and installed. The antennas shall be designed as a professional type inclusive of protection against icing.

- Frequency Band: 68 - 470 MHz
- Polarization: Vertical
- Antenna Gain: Approx. 15 dBi

The mounting, alignment and installing shall be included in the price of the tunnel radio system.

## 9. Desktop Station

In the control rooms desks in the equipment Room and Control Centre Desktop Stations for the Tunnel Radio System shall be installed. The functionality consists of listening and talk function for the individual channels.

The Tunnel Radio Desktop Station shall be modular and for all Channels. It shall be easy to operate and maintain. It shall consist of a handset, “gooseneck microphone”, a loudspeaker and push button key pad with a control display. This display shall indicate the status of the various channels. The transmitting shall talk with the desktop station into the Tunnel Radio System. Also, the possibility to play text conserves shall be given. Different pre-recorded messages (amount and text message shall be defined in accordance with the client) shall be stored.

The Desktop Station for Tunnel Radio System also can be used for the public address system, if required.

All necessary equipment shall be included in the price of The Tunnel Radio System.

### 7.2.16 Emergency Call and Service Telephone System

#### 1. General

According to IRC SP99 an emergency telephone system shall be installed for dispatching information regarding the occurrence of an accident to the Central Control and the Authorities, by person involved in or discovered the accident. Telephones shall be installed at intervals of 150 m, and in every relevant area of the tunnel (cross passages, Layby etc.). Emergency Pushbuttons to be activated by person involved in or discovered the accident shall be provided along the tunnel at intervals of 50 m.

An emergency telephone is a phone specifically provided for making calls to emergency services and is most often found in a place of special danger or where it is likely that there will only be a need to make emergency calls.

Whenever road user needs to contact control room in case of an accident or emergency, he will just lift the handset and call will be get connected to control room. Location from which user is dialling will also be indicated in control room. Voice over IP emergency telephone shall be used to communicate with the operation and maintenance centre. In these devices, a location identifier is also transmitted. The signalling and voice transmission is handled with the VoIP standard protocols, SIP / SDP (Session Initiation Protocol) and RTP (Realtime Transport Protocol). The driver initiates a call by lifting the receiver. Until the operator in the OMC answers the call, a message to wait and keep calm is being presented to the driver. Once the call is established, the driver and the operator can speak to each other. The call can be ended by the operator or the driver, who has to put down the receiver.

#### 2. Scope of Work

The emergency and service telephone system includes:

- Intercom-Stations
- Telephone Central Unit
- Desktop station
- Emergency call stations
- Service telephone stations
- Cabling

All equipment shall be designed and manufactured for an operation 24 h each day.

#### 3. Technical Specification-Emergency Call and Service Telephone System

a. The hardware of emergency call system shall be situated inside distribution panels.

b. The EPC / EM Concessionaire shall guarantee that functionality for emergency system shall be sustained over the whole tunnel length. The emergency telephones shall provide a reliable voice connection to the control system in case of an incident. The emergency call stations shall be built up very user friendly. On one hand, the emergency telephones are needed to grant persons in the tunnel an immediate connection to the Control Centre in case of emergency. On the other hand, along the whole tunnel as well as in the equipment rooms are also service telephones situated. These telephones are required for maintenance staff. The emergency and service telephones shall be combined in one system. They use the same transmission cable, but for the emergency system an immediate connection to the Control Centre must be given. The emergency call has a higher priority than a service call! The optical fibre ring shall run over switches.

c. In these switches optical fibre electrical converters shall be included. All telephones, that means the emergency and the service telephones shall be connected directly to those switches via RJ 45 plug-in connections. The intercom stations (emergency call central unit master and slave) at the equipment Room / Control Centre shall manage the telephone calls of the whole tunnel. So, the intercom station at the Equipment Room / Control Centre also shall initiate the distribution of the calls. That means, if an emergency call arrives, the information shall be prepared for transferring it to the control system via TCP / IP, because the main operation and receipt of the emergency call Shall be at the Control Centre. But also, in the Equipment Room desktop call stations, visualization and operations shall be possible. The intercom station shall be the interface to the Concessionaire of E&M. The Concessionaire of E & M shall take the information from the intercom station and shall transfer it to SCADA.

d. Furthermore, the tele control system shall enable the operation of these calls. That means, the emergency call's information shall be shown at the operator's screen and different functional processes shall be activated as described in Tunnel Control and Instrumentation System"

e. If a service telephone call arrives, the system shall check if this call is determined for the external (public) or internal telephone system. A distribution to the external (public) telephone system occurs via a Telephone Central Unit.

f. Generally the transmission of the whole emergency and service telephone system shall occur via intercom station at the Equipment Room / Control Centre. But if an optic fibre ring is interrupted, or a failure at any device is detected the system shall find an alternative route via the intercom station at the equipment Room / Control Centre. The required reaction and information transmission although shall be kept in permitted time. The operator in the Control Centre must be able to communicate with the person at the emergency telephone within a time of 3 sec. after the set of the emergency' call.

g. The Concessionaire shall guarantee, that even after a long break down of the power supply / the IP addresses of the telephone call system are not gone lost (whether emergency call nor service telephone system).

h. The telephone system shall be free structure programmed and scale able.

i. If somebody presses the push buttons at the hands-free speaking device at the emergency call station, immediately a visual and audible alarm shall be initiated at the equipment room and Control Room, and automatically all predefined functional processes shall be executed.

j. Apart from the information of speed also the information of failures shall be transmitted during an

k. emergency call. If a failure is detected (short circuit, interference voltage, etc.) the other parts of the system shall be untainted.

l. When the push button at the emergency call station is pressed, the voice connection -shall be initiated automatically to the tunnel operator at the Control Centre. As long as the emergency call is not answered by the operator, a pre-recorded text conserves shall be played (e.g. "your call is being answered soon, please stay calm" or similar). The exact messages shall be defined in accordance with the Client's instruction & requirement. Even the language (Hindi and or eventually English) shall be defined in accordance with the Client.

m. The voice communication between the operator and the fugitive shall be ended only if the operator disconnects.

n. Since the emergency call stations do not have a handset and that the tunnel is also used by maintenance personnel & others, it is necessary to ensure a good understand ability ("audio quality") although a hands-free speaking system is used. Also the volume shall be adjusted to the environment manually during initial operation.

o. The expandability for data transmitting shall be given. All push buttons and cabling shall be cyclic monitored. The zero-signal current also shall be monitored. If any failure is detected, fault signals shall be transmitted.

p. With the signals of emergency system no activation of any fire-programmes are allowed.

q. The maximum time, which may pass from the moment when an emergency call is set up till the operator answers the call, is 5 seconds.

r. The complete emergency and service call system shall be supplied by the UPS-System, so also in case of main power break-down the call system (especially emergency call system) keeps functioning.

s. The whole cabling from the distributor to the consumer shall be installed by the EPC Concessionaire (Telecommunication).

**4. Emergency Call Station (Voip)**

a. Emergency telephones shall be a single-line set, mounted in the emergency call cabinet of the Niches (with E&M equipment's), Maintenance room panels and in the Emergency Call Cabinets at the portals and Accesses.

b. Emergency telephones shall have a hands-free-speaking system. The emergency call will be activated by the fugitives with a push button. The push button shall be integrated in the front panel of the hands-free speaking system, so that they are very easy to press in case of emergency.

c. Only speaker, microphone and the push button of the emergency call system shall be mounted in the front panel of the emergency cabinet, so in case of communication, it shall not be necessary to open the cabinet. The rest of the emergency equipment shall be situated inside of the cabinet.

d. A two-way voice communication is necessary, so that the people can tell the operators about their situation in the tunnel, as well as the operator can calm the fugitives down and give them important instructions. The emergency call stations shall be resistant against the tunnel pollution (exhaust gases, smoke, etc.) as well as against the humidity ('weather proof type", IP 65) inside the tunnel tubes.

**5. Emergency Telephones (Ip-Telephones)**

a. IP-telephones shall include a microphone, a loudspeaker, a push button, etc. The protection shall be at least IP 65, the power supply 24 V-42 V AC. Further they shall contain 2 potential outputs and 2 inputs for potential free contacts.

b. The values are valid for emergency and service telephones. Hands-free speaking system shall be connected directly with the switches, by a suitable device. Emergency call stations throughout the whole tunnel shall be indicated via illuminated signs, mounted on the tunnel wall above the emergency call station. Size of these signs shall be 470 mm x 470 mm. The symbols of the illuminated signs shall be visible in both tunnel directions. These signs also shall be supplied by the UPS. But the signs and their cabling will be erected by the Concessionaire of E&M.

**6. Intercom Stations**

a. In the Control Room, master and slave intercom stations shall be placed. These stations execute the same function as a "Telephone System Server". On one hand these stations shall screen all calls of complete telephone system and on the other hand they are the interface to the transmission of the emergency calls to the tele control system and further on to the Control Centre. This transmission shall occur via TCP/IP. The service telephone calls shall be transmitted to the Telephone Central Unit.

b. The intercom stations shall be equipped with an interface to the tele control-system, so that automatic programmes can be initiated- for example, if an emergency call is initiated activated / the nearest camera will be connected / switched to the emergency video screen at the operators place automatically.

c. The intercom station shall be equipped with different modules. The modules are for preparing an interface to the SCADA, to the external (public) telephone system, desktop call station. Each module can operate no. of telephones.

d. The operating system of the emergency call system shall be realized with high-level language, but it also shall be object orientated. The operating system shall be stored in a Flash prom, so that a changing of e.g. EProms is not necessary for updating the operating system.

e. The following cards are required for the Intercom Station at the equipment Room / Control Room:

- Participant-cards TCP/IP for no. of participants
- Participant-card for connecting the desktop call station
- Network card ISDN with one basic terminal
- Network interfaces
- Digital audible coupling- and recording-card

f. The following cards are required for the Intercom Station at the equipment Room:

- Participant-cards 2-wired for no. of participants
- Participant-card for connecting the desktop call station
- Output card for relays, potential free
- Network card
- Network interfaces

g. Following features are required at the intercom stations:

- System Functions: 1-8 digit telephone numbers (also mixed), Frequency 300 Hz -16 kHz (analogue), feedback-protection, selective locking of features
- Voice Control: conversations in Open Duplex, Duplex or Simplex/ Volume separated adjustable for different functions
- General Conversation Functions: automatic conversation set-off for each participant; different pre-recorded messages (number and text shall be defined in accordance with the Client); discreet-function; locking of microphone

function; "occupied"-function; priority call function; call-back-request; connecting with other participants; retrieving of last call; speed dial for all participants, or separated for each participant; priority function.

- Functions with additional Interfaces: adapting with telephone-dial-devices/ output contact for system functions
- Group-calls
- Teleconferences with any participants, and predefined participants
- Audible transmitting of alarm inclusive an alpha numeric display
- Desktop call station: selecting of a set-up between service- and emergency-calls; displaying wait-information after set-up of a call, wire-detection for telephone stations, output-contacts for service- and emergency calls/ group-contacts for calls, manual calls - switching, automatic call-switching of calls depending on time (night I day), texts for display, changing to communicate via more desktop call stations at same time
- Bidirectional communication to control system
- Tests of functionality: periodic tests by testing loudspeakers and microphones / monitoring of wiring of call stations and their inputs, monitoring of network

h. SCADA generally shall process all emergency calls.

i. In the Control Centre also a desktop call station shall be situated. Therewith the operator can communicate per voice with the people at the emergency call stations very easily. Also, communication with the service telephones shall be possible with this desktop call stations. Those desktop call stations shall be connected to the Intercom Stations in the Equipment Room and Control Centre.

j. Each emergency call causes a visible and an audible alarm in the Control Centre, so the operator is immediately warned. Furthermore, the exact location of the incoming emergency call shall be Visualized on the operator's screen (tele control screen).

k. The operator may switch between different calls and sets up a connection from the Control Centre to any emergency station.

l. The complete emergency call system also surveillances itself, so malfunctions shall be kept to a minimum. The system shall also check itself for interruptions of connections due to wire breakage or open circuits. If such a failure is detected, the failure shall automatically be notified & sent to the tele control-system, where maintenance messages for the operator will be generated. So, failures will instantly be detected and can be repaired rapidly.

m. A further function of the Intercom Station regarding to the Service Telephone System is to provide a connection from the internal service telephone system to the external (public) telecom system with the Telephone Central Unit. The intercom station transmits the calls to the Telephone Central Unit. There it will be prepared and transmitted to the external (public) telecom system.

## 7. Voice Recorder

A voice recording system shall be linked with the Intercom Station in the Control Room Building. There all emergency calls (not the service telephone calls) shall be recorded and stored automatically. Since ·it is required to store the emergency conversations this digital voice recorder shall be able to record all emergency calls simultaneous. Also, the possibility to hear the calls to a later time again must be given.

**Table 12: TECHNICAL DATASHEET OF VOICE RECORDER**

| | |
|---|---|
| Frequency | 20-6800 Hz |
| Distortion factor | 0.2 % |
| Interference voltage span | -70 dB |
| Maximum possible storage time | 360 seconds for each emergency |
| Call Hard disc storage for voice recording | 80MB |
| Resolution | 12 Bit linear |

| | |
|---|---|
| Recess frequency | 16kHz |
| Output | 0.2-2V/200 Ohm |

**8. Desktop Call Stations**

a. The handling of emergency and service telephone calls by the operator shall occur via a desktop call station. With this station, the conversations shall be administrated, the inputs displayed and the outputs shall be controlled. The system of the desktop call station has to build up fully VoIP-digital and connected with corresponding interfaces to the intercom station.

b. This desktop station shall include a loudspeaker, a "gooseneck-microphone" and a keyboard with functional keys for talking, clearing, volume, etc. The possibility for digital monitoring of loudspeaker and microphone of the desktop call station shall be given. The display shall have a suitable resolution and number of rows and signs.

c. The individual desktop call stations shall have the possibility to operate parallel. The individual functions of the desktop call stations shall be able to be combined with each other. Also, the sequences of the incidents shall be displayed. The incidents have to cause an audible signal at the desktop station. A failure-key shall check all functions of the desktop call station. The individual function keys shall have status. LEDs.

d. All executed control functions of the desktop stations shall be transferred to the intercom station. The Desktop station shall be supplied by intercom station-with signals.

**9. Service Telephone System**

a. The Service Telephone System shall include telephones at the equipment room/ Substation/ control room. These telephones shall provide a possibility for voice communication for the maintenance staff. Because the service telephone and the emergency call system are combined, it shall be guaranteed, that the priority always shall be by the emergency call.

b. The service calls do not have to be recorded and stored like the emergency calls.

c. The Service Telephone System also shall have an outline to the external (public) telecom system (this outline will be erected by others, but the module therefore shall be provided by the EPC /EM Concessionaire of Telecommunication System) .

d. The system shall guarantee that calls from the substations can communicate directly together without exchanging through the central unit. This means the possibility of direct connection among each other shall be given. The transmitting of the service telephone calls to the external outline shall occur by a "Telephone Central Unit". This connecting equipment shall distribute the telephone calls.

e. Additionally, the possibility to dial from the substations through the outline to external telecom system is required. But for every substation this function shall be separately adjustable (locked I unblocked).

f. The functions are also required:

- Pick up of an internal or external call from every substation
- Call diversion to every substation
- Conference call
- Call diversion in the night to a certain telephone, or a certain outline.
- Blocking of out callings
- Creation of authorization levels (max. 3) for different kinds of callings (only internal callings, all callings, etc.)

**10. Main Telephone Apparatus (Ip Telephones)**

This telephone shall be positioned at the operator's desk. The handset shall be impact-resistant, made of plastic, coloured as required by the Client. Further it shall consist of a rectifier for hearing protection and a cord. But the operator even may communicate by the desktop call stations.

The telephone keyboard shall consist of phone buttons, speed dial keys, a display with at least 4 rows (as required to suit site requirements) and status LED next to the function keys.

This apparatus shall ring with a volume of at least 65 dB.

**11. Telephone Sockets**

The telephone sockets shall be mounted on walls or in distribution panels. The sockets shall be RJ45 type. The housing shall be impact resistant, made of suitable material and the colour as required of the Client.

### 7.2.17 Public Address System

**A. Design Requirements**

a. SYSTEM DESIGN

The design for the Digital Public Address/Voice Alarm System should meet the user and system requirements below.

b. USER REQUIREMENTS

The broadcasting system uses the same device to play the emergency broadcast. It has an emergency call microphone in the fire control centre for evacuating the crowds in specific zones when accidence happens and a paging microphone in the broadcasting centre to broadcast announcements and search notices.

The broadcasting devices located in the broadcasting centre or the specified location according to the user's requirement. The placement of the devices should meet the operating environment requirement and save up floor space. The amplifier capacity should comply with national standards and be with redundancy. Meanwhile, the emergency broadcast can achieve the linkage of the adjacent layers. Users can select the layers to be linked.

c. SYSTEM DESIGN REQUIREMENTS

The global mature and advanced technologies are critical for designing the public address system and only the broadcasting system incorporating mature and industry-leading technology and high-technology products can ensure the intelligence for buildings.

In the system design, advanced concepts, technologies and methods need to be adopted; system structure, product designs and wiring easiness also need to be considered.

d. FUNCTIONALITY AND RELIABILITY

Besides the technical advancement mentioned above, functional design, system structure, system performance, manufacturing process and after-sales support are also important as to ensure the reliability and stability of the system operation, maximizing the mean error-free time.

A mature technical platform and the rigorous manufacturing process are the bases of functions' realization. During the runtime, system should be able to discover and eliminate all the functional faults in time. The core components can achieve auto backup. System administrators can easily access the failures and work logs.

e. SYSTEM FUNCTION - SYSTEM DESIGN COMPOSITION AND PRINCIPLE

The system has placed broadcasting devices in Tunnel. The distributed control device (DCS) is integrated with many functions and supports the connection via Ethernet. It has loudspeakers output circuits to connect the loudspeaker in zones and network connection interfaces to connect to network paging control panel via Ethernet. Each DCS can connect up to 4 amplifier channels. The device has integrated amplifier switching matrix to support the redundancy switching and the general dry contact input/output interface to connect the external audio sources and dry contact interface of the linkage fire system. It has a built-in 1G memory to store the audios such as digital voice messages and the alarm tone of the emergency broadcast. This device can operate independently without the PC. It encompasses the functions like the audio playing, zone control, fault monitoring, log recording, volume control and amplifier switchover.

The control device for the system is customized. It has the LCD touch screen for operations, like zone selecting, calling, audio sourcing selecting, and emergency broadcast, monitoring and internal communication. The functions of the Programmable network paging console NPM can be configured using the configuration software.

f. KEY FEATURES -DISTRIBUTED CONTROL

This distributed design for the system is based on the tunnel profile to facilitate the connection of the loudspeakers in several nearby zones, which will make the control of the loudspeakers easier. The selected system devices should use the TCP/IP technologies and build on the standard network platform to ensure the extensibility, compatibility for multiple technology platforms and advancement of the system.

g. FAULTS DETECTION AND ISOLATION

The Faults detection function for the broadcasting system can automatically examine the host system, power amplifier,

power source, communication, and detect the open circuit, short circuit and grounding fault to generate the fault alarm and log.

When the grounding fault or short circuit occurs, the amplifier or the main controller of the system should isolate the circuit to ensure the operation of the main devices and normal circuits.

h. SERVICE BROADCASTING

The paging microphone allows users to make paging and broadcast search notices by zone. The paging microphone has a colour LCD touch screen. Users can configure the functions directly on the screen. Users can select the zone and audio source, adjust the volume, and enable the emergency broadcast by pressing the button on it. Paging microphones can intercommunicate. 255 broadcast priorities levels available. When the connected distributed control unit is out of order, a paging microphone can continue the intercommunication with other microphones in the network and precede the remote broadcasting configuration on other control units.

i. TIME SYNCHRONIZATION

Within the system, the controller can specify any main device as the main time source or choose a third-party system to be the time source. Other devices synchronize their time with the main time source to make sure the time is consistent in the system.

j. EMERGENCY BROADCAST

The broadcasting system can be linkage of the fire system to achieve the alarm function in the adjacent layers. The layers for linkage can be configured with the software as the requirements. Users can record the voice message for the emergency broadcast and save it in the host system. The emergency broadcast can start automatically (when linkage of the fire system) and manually. The broadcasting system has its own emergency microphone, which could be used to play emergency broadcasts and evacuate the crowds in specific zones.

k. AUTOMATIC AMPLIFIER SHIFT

The system has standby amplifiers. When a main amplifier fails to function, the standby amplifier replaces it automatically. After the main amplifier recovers, the system will use it instead of the standby amplifier in an automatic way.

l. BROADCAST RECORD

The DCS can record sufficient voice message (up to 1GB), and its contents can be customized. The voice message contains the emergency broadcasts for fires, such as evacuation and all-clear information, which are played by the digital speech synthesis system automatically (linkage of the fire alarm system) or manually. Four languages for the voice message are available. Users can select one of the languages to record the information.

m. LOG

The system can record the device fault log and operation log. Users can search information in the logs using time, devices, operators and log types as search criteria.

n. POWER SOURCE FORCED SWITCHOVER

The key devices, like DCS and amplifiers, have main power source and 24V standby power source. When the main power source fails to function, the standby power source is responsible for the power supply.

o. DISTRIBUTED CALL STATION

The distributed call station can call the specified zones. The call station has remote control function, which can control emergency broadcast, zone audio sources and external devices.

p. AUTOMATIC VOLUME CONTROL

The volume of the system can adjust automatically responding to different levels of environment noise in the crowded areas.

q. LOCAL & REMOTE MONITORING

Users can monitor audio sources status via local distributed control units and remote call stations.

r. EMERGENCY BROADCAST - Emergency broadcast Requirement:

i. Forced Switchover (Auto/Manual): Once the emergency broadcast is triggered by a remote-control microphone or other external devices (fire alarm system) the system will play the recorded voice message (alarm and evacuation information) for fire emergency or the information from the emergency microphone until the all-clear.

ii. The system will switch to emergency broadcast in 3 seconds.

iii. The signal tones and voice messages (alarm and evacuation information) of the Emergency broadcast system are stored on the voice storage flash or SD card, which will not be ageing or lost. Users can play them in all zones.

iv. Emergency broadcast system should have system testing function as a standard configuration. The testing for the system can enable the operator to ensure the normal operation for the system all the time. The testing of emergency broadcast should be enabled via the software instead of playing the actual emergency broadcasts and causing public's panic.

v. Emergency broadcast system should achieve the automatic amplifier shift. Once an amplifier fails to function, the standby amplifier replaces the breakdown amplifier automatically without changing the input and output circuits of the amplifier manually.

vi. Emergency broadcast system should have pre-recorded emergency broadcast messages. The system should be able to edit and record the alarm and evacuation message. The priorities of the emergency broadcast can be programmed. DCS should be with a PTT emergency microphone, with which operators can announce real-time evacuation notices when emergency happens.

vii. Users can listen to stored or audios about to play to avoid playback error message which may lead to crowd panic.

viii. Language kinds should meet the user's requirements. There should be spaces left for the tags to facilitate users to stick related prompts for management.

ix. The system can automatically record voice messages sent by emergency microphone. Users can listen to and broadcast voice messages.

x. The linkage signals of the emergency broadcast uses the volt-free contact. All signals are from the fire control Centre. The number of cables is the same as the fire control Centre number.

xi. Can achieve the linkage of the adjacent layers. Users can select the layers to be linked via software configuration.

xii. When system switches to fire alarm mode, fire floor plan will pop up in the operating interface, directly showing where the fire happens. Operators can select specific zones and activate the warning and evacuation broadcast on the operating panel.

xiii. The loudspeakers allow the 3-wire forced volume control switchover.

s. CIRCUIT DETECTION

It is able to detect every zone's status to ensure the working order of the circuits and report faults in time. When a short-circuit error takes place, the device isolates the zone where error happens to protect the amplifiers and to cut off its impact on other zones.

**B. Functional Requirements**

a. DEVICE SELECTION

The system should be based on the TCP/IP network technologies with high level of integration and flexible configuration to meet various requirements. It is designed for the emergency broadcast enabling fire emergency broadcast functions like automatic fire warning, voice message pre-setting, emergency calling, emergency call recording and circuit monitoring. The device is accordance with the Automatic Control System for Fire Protection (GB16806) and Standard EN 54-16, IS-11360

With public address and voice alarm system integrated into one, the system should solve the duplication of investment and security risks and other problems caused by two individual systems. The distributed intelligent systems should be capable of accessing the 10/100M Ethernet network and multiple audio sources from the network. It supports connections in the Ethernet and the networking for several other control systems to perform centralized and distributed management via software. This product should be suitable for medium-scale and large-scale requirements

b. TECHNICAL CHARACTERISTICS -HIGH INTEGRATION

The controller should be able to integrate audio source storage, network audio reception, voice broadcasting, audio matrix, volume control, and monitoring, troubleshooting and main/standby amplifier switch functions together.

c. SAFETY

The system should be GB16806/EN54-16 compliant and can work in severe environment. It can be used to broadcast in case of emergency to disperse and evacuate people. It is a great guarantee for people's life security

d. ETHERNET BASED EXTENSION

The central controller should be able to connect over the Ethernet without any external device. The configurable Network Paging Microphone could be placed anywhere in the Ethernet, which will enable the following:

- The method of distributed installation can save the cost of wiring.
- If the band width is sufficient, it can use current internal network.
- Provide plentiful network audio sources.
- Centralized management of the system via system software.
- Control the local or global broadcasting by the manner of permissions.
- Easy to upgrade

e. MULTIPLE AUDIO SOURCES SUPPORT

The system supports the audio sources from emergency microphone, network audio, ancillary line input, build-in audio/music files and web microphones.

f. PRIORITIZED CONTROL

The system supports 255 priorities. Users can configure it in any way they want and realize all kinds of prioritized broadcasting controlling.

g. AUTOMATIC VOLUME CONTROL FUNCTION

In places of crowded people and loud noises, users can install a noise detector, which can help control the broadcasting volume automatically to ensure sound's intelligibility.

h. LOCAL AND NETWORK MONITORING FUNCTION

With the built-in loudspeaker of controller or Configurable Network Paging Console, users can monitor each zone's broadcasting. The monitoring volume can be adjusted.

i. TOUCH SCREEN

Programmable network paging console (NPM) is equipped with a touch screen. Users can operate on the touch screen to configure multi-zones settings without the need to extend hardware key modules, saving floor space on the desktop.

j. TROUBLE SHOOTING FEATURE

The ASD troubleshooting technology can support the system to automatically detect the failure of the main power, standby power, amplifier circuit, amplifier protection/power, software, communications and loudspeakers etc. It can also locate the failure for maintainers to repair or replace the fault units.

k. LOUDSPEAKER CIRCUIT DETECTION

The SIM loudspeaker circuit detecting technology helps monitor loudspeaker circuits' statuses. When short-circuit or open-circuit faults are found, the device will send a warning automatically. The software can display all the circuit faults for maintenance's convenience. Usually, a loudspeaker's short-circuit fault will activate the amplifier protection, affecting the working order in other zones. SIM solves this problem by automatically isolate the short-circuited zone where fault is found.

l. AUTO-BACKUP

Risk Free auto-backup technology focuses on realizing the main units', including servers' and amplifiers', backup and switchover functions. A server machine is paired up with a standby one, while a standby amplifier can serve as the backup machine of one, two or three main amplifiers. When faults are detected on the main machines, the system will switch over to the standby one.

m. INPUT/OUTPUT TRIGGERING

This system has input/output interfaces which can be triggered by dry contacts. Engineer staffs can configure the contact input to achieve the broadcasting control by the external device (linkage of the fire system). The contact output

can be used to control the external devices for the volume, forced switchover and so on. The contact output interface can be linked of the broadcasting operations.

n. VOICE RECORDING

Besides in the system server, the controller should have 1GB solid-state storage to store the alarm voice, service voice and other audio files. Users need to upload the audio files to the device using the specified configuration software.

o. VOICE ALARM

This system is designed in accordance with the EN54-16 Standard and national standard GB16806. It is full featured for the fire alarm. When the fire occurs, the system will play the pre-set voice information. Then it can play the evacuation information for the zones with fires and the fire alarms for the nearby zones. The system can set several kinds of language for voice information, which can be played using the operation panel.

p. ONE CLICK TECHNOLOGY

To increase operation's convenience, One Click technology is developed with which broadcasting can be started by clicking only one key. The operation shortcut can be configured with system management software and network paging console.

q. MULTICHANNEL DIGITAL POWER AMPLIFIER

Multi-channel digital power amplifiers with CLASS-D technology design should be used in the system. Its output efficiency is more than 80%, which can reduce the power costs. Besides low power consumption, it is small in size. In this case, several amplifiers can be put in the same chassis to save the space. This kind of power amplifier has the features as below:

i. CLASS-D Amplifier saves the energy with high efficiency.

ii. Channel number can be 1, 2 or 4

iii. 100V or 70V output is used for each channel.

iv. Support balanced input or unbalanced audio input mode.

v. Cooling mode is forced air-cooling mode.

vi. Able to limit output voltage automatically.

r. FLEXIBLE CONFIGURATION

This system allows users to customize the configurations flexibly using the specific software. The engineering technicians and maintainers can configure the built-in audio sources, keys' functions, troubleshooting, audio source play modes, broadcasting priorities and contact input/output and other customized operations the One Click functions. The configuration software for this system is used to configure the hardware. The default configuration for the device contains only the basic functions. Users need to work on each setting, including basic parameters, troubleshooting, broadcast pre-set and key events and so forth.

s. SYSTEM MANAGEMENT SOFTWARE

The system management software can run on the Windows XP/Windows Vista/ Windows 10 or latest operation system. It can communicate with the system via the Ethernet. The operation is as simple as below:

t. SYSTEM CONFIGURATION

- Configure the components and functions of the system management software.
- Configure the devices for the server.
- Configure the electronic map or operation interface.
- Configure audio sources and pre-set broadcasting operations.
- Drag the maps, icons and buttons to modify the layout on the server operation interface.
- Configure the managing scope and authorities for software on the client end.

u. USER MANAGEMENT

It can add, edit and delete users and manage access control of the users.

v. BROADCASTING CONTROL

The broadcasting control function allows users to manage all the broadcasting businesses and to manage the broadcasting management client ends.

w. SYSTEM STATE MANAGEMENT

The software can obtain broadcasting states of each device in the system. The buttons and icons representing devices or zones will be green when all functions are normal, and will turn red when fire occurs.

x. SYSTEM WARNING

System Warning Function allows for centralized management of device failure states in the system and recording the fault log automatically in the log module. When the system detects failure, the interface of the system management software will give out audible & visual alarm. Failed device unit is yellow. Users can accurately locate the failure unit using the interface of the system management software.

y. LOG MANAGEMENT

System can record and store all system operations histories and failure events for future analysis. Work log and failure log will be stored in separate memories and cannot be deleted manually. Only the logs of the latest one year will be stored. Users can query the logs according to time, workgroup, device, etc. and export the result logs.

z. VOICE SYNTHESIS

The system management software provides the interfaces for the third-party voice synthesis software. It can convert the text words into voice for playing.

aa. AUDIO MANAGEMENT

It allows users to perform centralized management of the audio files on the server, and to play them on the network. The audio management function can convert the audio source files in different format into the specified formats of the system. It can put the audio files to the specified broadcasting zones by configuring the pre-set broadcasting operation.

bb. DEVICE DESCRIPTION -DIGITAL INTEGRATED SYSTEM MANAGER / CONTROLLER

The Digital Integrated System Manager is hereinafter referred to as the DCS.

The DCS is the control equipment in the system designed for extending the number of loudspeaker zones, and can support multiple sound source files for broadcasting. The system integrates with functions such as the sound source file storage system, the network audio broadcasting system, the loudspeaker zone control system, and the system for monitoring and diagnosing faults.

The DCS offers various features, which are listed below:

i. Supports the manual selection of sound source files, zone buttons, and can be directly operated.

ii. Supports emergency microphone input for emergency broadcast in the event of, for example, a fire evacuation.

iii. Includes different indicator lights that identify system running states.

iv. Performs remote paging and broadcasting operation through the Configurable Network Paging Console (NPC).

v. Includes 8 zone outputs. The number of zones can be configured through the software.

vi. 4 auxiliary inputs that can connect to external sound source equipment such as a CD player or tuner

vii. 4 auto volume control input ports that can set the phantom power supply and gain of each input.

viii. Auto loudspeaker circuits, short-circuit and open-circuit detection.

ix. A fuse protects the main power supply. In the case of a power supply short circuit within the DCS, the system automatically disconnects the main power supply.

x. Built-in loudspeaker that can monitor the zones and sound sources, as well as monitor the network audio through the NPM / NPC.

xi. Contains 1GB of built-in flash memory that can store recorded voice files so as to full fill functions such as voice information broadcasting and voice synthesis

xii. Can simultaneously broadcast four types of sound sources, such as voice audio sources and external input or network audio sources.

xiii. Can automatically record operation and fault logs, and can store up to 10,000 logs of each log type (operation and fault log types).

xiv. Supports switching between the main and backup power amplifiers, and is capable of configuring the standby mode.

xv. Contains a self-test function.

xvi. Supports automatic fault diagnosis.

xvii. Supports broadcasting volume adjustment.

xviii. Can define the zone and sound source functions. Button function description labels are also easy to install.

xix. An audio matrix enables broadcasting any audio source in any zone.

xx. Supports fire emergency broadcast mode so as to improve personnel evacuation efficiency in case of an emergency.

xxi. Supports broadcasting designated recorded voice audio at a designated time so as to allow for unattended broadcasting.

xxii. Capable of system extension through an Ethernet network.

cc. 600W HIGH EFFICIENCY POWER AMPLIFIER

The DA has the following main characteristics:

i. Energy-efficient CLASS-D power amplifier

ii. Contains 1/2/4 independent channels

iii. Each channel has 100V or 70V of output

iv. Supports balanced or unbalanced audio input

v. The DA is cooled through forced air-cooling

vi. Provide automatic re-settable over current, overload, overheating, overvoltage, under-voltage and DC protection

dd. CONFIGURABLE NETWORK PAGING CONSOLE

The Configurable Network Paging Console is hereinafter referred to as the "NPM"

The network paging microphone (NPM) connects to the system and related devices to transmit audio and control information through the Ethernet network. The NPM is used for paging, controlling broadcasts, monitoring zones, and for using the bidirectional intercom function.

The NPM has the following characteristics:

i. Lightweight and innovative patent outward design. Support embedded desktop installation

ii. 4.3-inch colour LCD touch screen. Can display system status and be operated for zones and groups' division or global paging and broadcast control

iii. Simple and intuitive user interface

iv. Can connect with up to 20 units. Button numbers can be added via software configuration

v. Built-in monitor loudspeakers. Can utilize functions like zone monitoring and two-way intercom between stations.

vi. Digital audio processing to avoid acoustic fidelity distortion

vii. Can intercommunicate with other paging microphones and DCS in the network even when the connected DCS is not running

viii. 3 shortcut buttons: microphone talk mode switch, select all function and emergency broadcast

ix. Has one audio input and output port for playing BGM from a CD source or for recording an output.

ee. VOLUME CONTROLLERS

Volume Controllers have the following four types: 6W, 30W, 60W and 120W respectively. The features are as follows:

i. Build-in 24V DC forced cut-off relay;

ii. 5 volume levels control;

iii. Applicable to 3-wire, 4-wire and 6-wire systems;

iv. Standard 86X86 installation base-shell.

ff. LOUDSPEAKERS

Horn Loudspeaker - 15W Horn Loudspeaker with IP66 protection

**C. Emergency Voice/ Alarm Communication**

The EVAC system shall contain all equipment required for audio, communication, signalling and supervisory functions. This shall include speaker zone indication, digital voice units, and microphone.

**Function: The EVAC system equipment shall perform following functions:**

- Operate as a supervised dual channel emergency voice communication system.
- Operate as a two-way emergency communication system control centre.
- Supervise condition of every connection circuit.
- Audibly and visually annunciate any trouble condition of tone generators and digital voice units required for normal operation of the system.
- Provide all-call activities through activation of a single control switch. Provide selectable zone calling.
- Provide automatic, digitally recorded voice messages or field-programmed through the microphone.

The system shall be modular in construction and shall be capable of being field programmable without requiring the return of any components to the manufacturer. The system and associated equipment shall be protected against unusually high voltage surges or line transients.

**a. GENERAL**

A Public Address System shall be provided to inform / warn maintenance and service staff and give instructions to people in abnormal conditions during incident. Therefore, loudspeakers shall be installed every 60 m or as per drawing in the main tunnel tube. Operator terminals shall be in the Control Room Buildings at the portals or in the Control Centre.

**b. SCOPE OF WORK**

- Loudspeakers
- Amplifiers (wide-band amplifiers)
- Digital Sound Processing Unit
- E/O and O/E Converter
- Public Address Central Unit
- Cabling

**c. TECHNICAL SPECIFICATION**

The loudspeakers shall be fed by multi-range amplifiers, which shall be supplied with audio-data via electric loudspeaker cables from the Control Room Buildings and Niches. At the Control Room Building the central unit for the Public Address System shall be situated. This central unit shall be connected to the Control Centre by use of the tele control system. The central unit shall be used as interface to the tele control system. The Concessionaire of E&M shall take the signals from there. At the Control Room Buildings / at the Control Centre, a control unit with a microphone for the announcements shall be situated. With these control units different circuits of loudspeakers can be switched on (e.g. all loudspeakers ON; only the loudspeakers near the accident ON; etc.) and the operator may control which way of voice communication via the loudspeaker shall be (if the operator speaks directly into the loudspeakers, or if predefined text conserves shall be played).

The loudspeakers itself shall work with supply-voltage (from the amplifiers).

With the loudspeaker arrangement of 60 m distance between each other as per final design compliance, to design system and best acoustic shall be provided. But nevertheless, it is very critical to operate a Public Address System in a tunnel. So, the Concessionaire has to guarantee a good understand ability and test the loud speaker system on a

certain level of 'get the spoken words:

- even if no vehicle is in tunnel
- a vehicle runs into a tunnel (maybe 2 km away)
- a vehicle runs out of a tunnel
- a vehicle stands close/next to the passengers on the walkway

The dimension of the facility shall be determined in the way that one loudspeaker device, in a range of 1 to 4 kHz1 can reach a minimum sound pressure level of 110 dB(A) in a distance of 3 m / as approved.

**d. LOUDSPEAKERS**

Loudspeaker inclusive associated equipment as well as construction.

Technical Data:

Material: - Aluminium

Degree of protection: - IP 65

Nominal Power: - 15 W

Nominal Voltage: -100 V

Frequency range: - 200- 5000Hz

Sound pressure level: - min. 114 dB(A)

**e. AMPLIFIER**

The amplifiers shall be solid state amplifiers in cabinet of industrial design. The amplifiers shall be installed in the cabinets to provide good access to the control elements, control lamps, test and monitoring sockets and cables. The amplifiers shall be marked clearly readable and permanent at the front side.

**CHARACTERISTICS**

Remote control with inrush current limiting

Wear-free digital level control

Switch-On-noise suppression

Status signals for operation, standby, test

LED control display

**TECHNICAL DATA**

Construction type: Cabinet / by EPC Concessionaire / as approved

Inputs: 4xAudio-Lf-IN

Power: 4x 100 W

Distortion factor: 0 / less than 1 %

Frequency range: 60-15000 Hz

Output: 70V/SO Ohm- 100 V/100 Ohm, with overload and short circuit

protection Overheat protection

**f. DIGITAL SOUND PROCESSING UNIT**

The signal preparation shall be realized with a 24-bit AID-converter and the internal signal preparation with 32-bit floating-point signal processor, which can control each output channel, and as well as the total signals independently in gain and delay guides.

The digital sound processing unit shall be installed in the cabinets to provide good access to the control elements, control lamps, test and monitoring sockets and cables. The digital sound processing unit shall be marked clearly readable and permanent at the front side.

**CHARACTERISTICS**

Input with 1 x high-pass· and 1 x low-pass

Output with l x high-pass and 1 x low-pass

Status LEDs

Remote power on

Self-Monitoring

**TECHNICAL DATA**

| | |
|---|---|
| Construction type: | Cabinet |
| AID-Converting: | minimum 16 bit |
| Sampling rate: | 48 kHz |
| Inputs: | 1 x Audio-LF-Input (XLR) |
| Input impedance: | 10 k Ohm |
| Outputs: | 4 x Audio-NF-Outputs (XLR) |
| Output impedance: | 50 Ohm |
| Distortion factor: | less than or equal 0.01 % |
| Frequency range: | 50 - 20000 Hz |

**g. E/O- O/E CONVERTER**

The transmission of the low frequency signals from the loudspeaker central unit in the Control Room Building South to the optic fibre patch panels and further to the DSP units and amplifiers in the Niches and E & M niches shall be realized with Electrical/ Optical or Optical/ Electrical Converters.

**TECHNICAL DATA E/O**

| | |
|---|---|
| Type: | Cabinet / as approved |
| Input LF: | LF signal |
| Output optical: | 2x ST or SC for Multimode-optical fibre cable |
| Transmitted: | up to 2000 m |
| Power supply: | 24VDC |

**TECHNICAL DATA O/E**

| | |
|---|---|
| Type: | Cabinet |
| Output optical: | 2x ST or SC for Multimode-optical fibre cable |
| Output LF: | LF signal |
| Power supply: | 24VDC |

**h. PUBLIC ADDRESS CENTRAL UNIT**

The Public Address Central Unit shall be installed with all necessary units (input modules, relay modules, control unit, etc.).

The necessary equipment shall be installed in the distribution cabinets to provide good access to the control elements, control lamps, test and monitoring sockets and cables. The equipment shall be marked clearly readable and permanent at the front side.

**THE PUBLIC ADDRESS CENTRAL UNIT SHALL CONSIST OF FOLLOWING MODULES I EQUIPMENT**

1x basis equipment with central control and operation unit

1x extension rack

1x digital voice recording unit

1x microphone I Line-In input module

1x communication terminal

1x relay module (blocking, error massages)

1x Line module (8x group lines, 1x connection to LAN)

**INTERFACE TO TUNNEL RADIO SYSTEM**

| | |
|---|---|
| Low frequency range: | 300 - 3400 Hz |
| Output level: | 6 dBm ± 2 dB |
| Input level: between: | 6 dBm and - 20 dBm |
| Impedance: | 600 Ohm |
| Noise level: | < - 46 dBm |
| Distortion factor: | < 10 % |

Furthermore, a voice recording system shall be linked with the Public Address System. There predefined text conserves shall be stored. The different text contents of those conserves shall be in accordance with the Client.

The text conserves (messages) shall be retrieved by the tele control system or even by the Tunnel

Radio System, so that it is possible to reach the voice messages even through the Tunnel Radio System.

**i. DESKTOP STATION**

The Desktop Station of the Tunnel Radio System also shall be used for the Public Address System.

**j. LOUDSPEAKER CABLE**

3 core 2.5 sqmm FRLS copper cable, as per Technical Data Sheet shall be used for connecting the loudspeakers. Depending on the used loudspeaker types by the customer, shall provide fitting system-cabling. The predefined values of the loudspeaker manufacturer shall be kept as per approved make.

**k. OPTICAL FIBRE CABLE**

The optical fibre cabling, which transfers the information from the Control Room Buildings to the EM-Niches shall be A-DF(ZN)2Y 12x12 E9/125 or as specified. This cable will be installed by the Concessionaire of E&M.

The required fibres shall be used by the Concessionaire of Telecommunication for the Public Address System (plug-in system - E2000 / as specified and approved).

**Table 13: TECHNICAL DATA SHEET FOR DIGITAL INTEGRATED SYSTEM MANAGER / CONTROLLER**

| Parameter | Value |
|---|---|
| Power Supply | |
| Main power supply | ~100-240V, 50/60Hz |
| Backup power supply | DC 21.5V-28.5V |
| Main power fuse | T2AL 250V |
| Max. input power | 120 W |
| Rated power | 50 W |
| Audio Input | |
| Auxiliary input | 0dB |

| Parameter | Value |
|---|---|
| Input impedance | 20 kΩ |
| Frequency response | 60Hz-16KHz |
| PTT microphone input | -51dB |
| SNR | >85dB |
| Audio Output | |
| Audio output channels | 4个 |
| Output signal | 0dB |
| Record output | 0dB |
| AVC Input | |
| Channels | 4个 |
| Input signal | -50dB/0dB, configured by switch |
| Input impedance | 20KΩ |
| Phantom power | DC 24V, configured by switch |
| Frequency response | 60Hz-16KHz |
| SNR | >65dB |
| Loudspeaker Circuit | |
| Output channels | 8, with circuit fault detection function |
| Max. output load power | 250W |
| Trigger Input / Output | |
| Trigger input ports | 8 |
| Trigger output ports | 8 (NO, NC and COM) |
| Max. working voltage | AC 250V/DC 30V |
| Max. working current | 2.5A |
| Others | |
| Monitoring loudspeaker | 10W/8W |
| Ethernet speed | 10M/100M |
| Ethernet interface number | 4 |
| Storage space | 1GB |

| Parameter | Value |
|---|---|
| Work Condition | |
| Humidity | < 95%, without condensing |
| Working temperature | -10°C~+55°C |
| Storage temperature | -40°C~+70°C |
| Specification | |
| Dimension (W×H×D) | 482 mm×88 mm ×420mm |
| Mount dimension (W×H×D) | 580mm×235mm ×552mm |
| Net weight | 9.3Kg |
| Gross Weight | 12.5 Kg |

**TABLE 4:TECHNICAL DATASHEET FOR POWER AMPLIFIER**

| **600W HIGH EFFICIENCY POWER AMPLIFIER** | |
|---|---|
| Rated output power | Max. 600W |
| Main power supply voltage | AC 220V -15% - +10%50-60Hz |
| Backup power supply voltage | AC 220V -15% - +10%50-60Hz |
| Main power supply fuse | T10AL 250V |
| Loudspeaker output | 100V / 70V |
| Frequency response | 70-15KHz (+1dBto -3dB) |
| Input sensitivity and impedance | 1.414VRMS& 20K ohm |
| Output voltage/impedance | 100V/40ohms, 70V/19.6ohms |
| Signal-to-noise ratio (SNR) | >90dB |
| Nonlinear distortion | <0.1% (1KHz,1/3 rated output power) |
| Number of channels | 2 |
| Environment humidity | < 95%, without condensing |
| Working temperature | 0 to +40°C |
| Storage temperature | -10°C to +55°C |
| Product dimensions (width × height × depth) | 88mm × 440mm × 440mm |

**TABLE: 15TECHNICAL DATASHEET FOR PAGING CONSOLE**

| CONFIGURABLE NETWORK PAGING CONSOLE | |
|---|---|
| Power supply voltage | DC 24 V |
| AUX input | 0 dB |
| AUX input impedance | 10 KΩ |
| Frequency response | 60 Hz – 16 KHz (local input signal) |
| Microphone input | -51 dB |
| Audio output | 0 dB |
| Monitoring loudspeaker | 2 W/8 Ω |
| Monitoring sound pressure level | Higher than 65 dB and lower than 115 dB (1 m in front of where the audio is being output) |
| Operating temperature | -10 °C to +55 °C |
| Storage temperature | -40 °C to +70 °C |
| Humidity | <95%, without condensation |
| **VOLUME CONTROLLERS** | |
| Rated power | 6W/30W/60W/120W |
| Supply voltage | 100V |
| Frequency response | 50Hz~20KHz |
| Attenuation | 5X2dB + off |
| Current consumption | 20mA, 24V DC |

**TABLE 5: TECHNICAL DATASHEET FOR LOUDSPEAKERS**

| HORN LOUDSPEAKERS | |
|---|---|
| Max Power | 25 W |
| Rated Power | 15 W |
| Power taps @ 100 V | 15 W / 7.5 W |
| Sound Pressure Level at 6W/1W (1kHz, 1m) | 110.3 dB / 98.5 dB |
| Frequency range (-10 dB) | 500 Hz – 5 kHz |
| Dispersion Angle (1kHz / -6dB) | 140° |
| Protection | IP 66 |

| | |
|---|---|
| Rated Input Voltage | 100 V / 70 V |
| Rated Impedance | 500 Ω / 1 kΩ |
| Connection | Cable |
| Dimensions (diameter x height) | 225 x 165 x 240 mm |
| Weight | 1.38 kg |
| Color | White (RAL 9010) |
| Case Material | ABS |

| LIST OF APPROVED / LIKELY SOURCES | | |
|---|---|---|
| | | |
| **S. No.** | **DESCRIPTION OF ITEMS** | **MANUFACTURER'S NAME** |
| **Electrical System** | | |
| 1 | Diesel operated Power Generating Engine | Cummins India<br>Caterpillar<br>Koel Green (IEC)<br>Sterling & Wilson<br>Sudhir Power<br>Jackson<br>Kirloskar |
| 2 | Power Transformer Oil filled (33kV / 11kV) | ABB<br>BHEL<br>Schneider<br>Siemens<br>Crompton Greaves<br>Alstom (Areva)<br>Voltamp<br>Tesla Transformers Ltd.<br>Sudhir Power |
| 3 | Distribution Transformer Dry Type (11kV / 433V) | ABB<br>BHEL<br>Schneider<br>Siemens<br>Crompton Greaves<br>Kirloskar<br>Alstom(Areva)<br>Voltamp<br>Tesla Transformers Ltd.<br>Sudhir Power<br>Legrand |
| 4 | Synchronizing Panel, Auxiliary Panel and Motor Control Centre | Tricolite Electrical Industries<br>Jackson Engineers Limited<br>Adlec Control System<br>Schneider<br>Sudhir Power<br>Legrand<br>L&T |
| 5 | Power Distribution Panels and Distribution Boards | Schneider<br>Siemens<br>ABB<br>Legrand<br>Adlec<br>L&T |

| | | |
|---|---|---|
| | | Tricolite |
| 6 | Automatic Transfer Switch | ASCO<br>Cummins<br>GE Power Control<br>Socomec<br>L&T |
| 7 | Air Circuit Breaker (3/4 Pole), MCCB, MCB, Switch Fuse Unit, HRC Fuse, RCCB, Aux. Contactor, Changeover Switch | Schneider<br>Larsen & Toubro<br>Siemens<br>ABB<br>Legrand |
| 8 | Potential Transformer, Current Transformer | AE<br>L&T<br>Siemens<br>Schneider<br>Crompton Greaves<br>Kappa<br>Matrix<br>Pragati |
| 9 | Instrument Transformer | Precise<br>G&M<br>Matrix<br>Legrand<br>Schneider<br>AE<br>Kappa Pragati |
| 10 | Numeric type Protection Relay, Generator Protection Relay, Automatic Power Factor Correction Relay | L&T<br>Siemens<br>Schneider<br>ABB<br>Alstom<br>GE |
| 11 | Indicating Lamps LED Type, Push Buttons | L&T<br>Siemens<br>Schneider<br>ABB<br>Legrand<br>Rishabh |

| | | |
|---|---|---|
| 12 | Overload Relays with built in Single Phase preventer | Schneider<br>Larsen & Toubro<br>Siemens<br>Alstom<br>Legrand<br>ABB |
| 13 | Capacitor Control Relay, Power Capacitor Panel | EPCOS<br>Legrand<br>Schneider<br>ABB<br>L&T<br>Siemens<br>Neptune |
| 14 | Electronic Digital Meters, Electro-Magnetic Meters | Trinity<br>Conzerv system Pvt. Ltd.<br>Automatic Electric<br>ABB<br>Siemens<br>Schneider<br>HPL<br>Socomec<br>L&T |
| 15 | Static Power Meter and Logger | Conzerv System Pvt. Ltd.<br>Ducatti<br>Neptune<br>L&T |
| 16 | 33kV, 11kV XLPE copper conductor armoured Cables | Universal Cables<br>Havells<br>KEI<br>Polycab<br>RPG<br>Finolex<br>Gloster |
| 17 | 433V XLPE insulated e-beam FRLSLH Cables | RR Kabel<br>Universal Cables<br>KEI<br>Havells<br>Finolex<br>Polycab |

| | | |
|---|---|---|
| 18 | 33kV, 11kV Cables with Fire Protection Cover as per specifications | KBS Cable<br>Eastern Copperfields Trading Inc.<br>Legrand<br>MEM<br>Schneider<br>Havells<br>Finolex<br>Polycab |
| 19 | LT Joining / Tremination Kit, Cable Glands double Compression, Cable lugs | Raychem<br>Brass Copper & Alloy Ltd<br>Dowell's<br>3M<br>SV Systems<br>Xicon<br>Comet<br>M-Seal<br>HMI<br>Trinity Touch |
| 20 | PVC insulated copper conductor stranded flexible wires | Finolex<br>R.R.Kabel<br>KEI<br>Havells<br>RPG<br>Polycab<br>Grandley<br>Rallison<br>CMI<br>Delton |
| 21 | SS Conduit, PVC Conduits, Accessories for SS Conduit | BEC<br>Polycab<br>RMG Steels Pvt. Ltd.<br>Vimco<br>Steelkraft<br>JPC<br>Flexicon<br>Plica India Pvt. Ltd.<br>Trinity Touch |
| 22 | Timer | L&T<br>Siemens<br>Schneider<br>Minilec |

| | | |
|---|---|---|
| 23 | Emergency Power Supply-UPS | Schneider<br>Eaton<br>Numeric<br>Emerson<br>Delta |
| 24 | Ni-Cd batteries | Exide<br>Standard<br>Hitachi<br>Amaron<br>Amara Raja<br>AMCO<br>Quanta<br>HBL<br>Statcon<br>Panasonic |
| 25 | Battery Charger | Volstat<br>Caldyne<br>Amco<br>Hitachi<br>Exide<br>Panasonic |
| 26 | Cable Trays, Cable Ladders | Rico Steel<br>Cablofil<br>Legrand<br>Obo-Bettermann<br>SV Systems<br>MEM<br>Schneider |
| 27 | Bus Duct | Schneider Electric<br>Legrand<br>Siemens<br>L&T<br>C&S |
| 28 | MS Pipes, GI Pipes | Tata Steel<br>Jindal<br>APL Apollo<br>Jindal Star |
| 29 | MS Pipe / GI Pipe Fittings | Jainsons Industries<br>Bharat Forge<br>Pipeline Products<br>Easyflex |

| | | |
|---|---|---|
| | | Unik<br>Jindal Steel<br>C-Brand |
| 30 | 33 kV / 11 kV Insulating Mats | DL Miller & Co. Ltd<br>Premiere Polyfilm Ltd.<br>RMG Polyvinyl India Ltd.<br>Duratuff<br>AM Vinyl<br>Jyoti<br>Electromat<br>Padmini<br>Trinity Touch |
| **FIRE DETECTION & FIRE FIGHTING SYSTEM** | | |
| 31 | Fire Alarm System | Futech<br>Multisystems<br>Samay Project Services<br>Firepro<br>Vimal Fire Groups |
| 32 | Soft Fire Wall, Fire Barrier | Siemens<br>Listec<br>Cushion S90<br>Hilti<br>3M |
| 33 | Linear Heat Sensor, Smoke Detector, Fire Detection Unit, Control & Monitor Modules, Main Control Panel, Manual Call Stations | Siemens<br>Listec<br>LST<br>Safeguard<br>Edwards<br>Techfab System<br>AP Sensing<br>Samay Project Services<br>Honeywell<br>Vimal Fire Group |
| 34 | Split A.C., Air supply unit, Ventilation Ducts, Control Panels for Room Ventilation | Blue Box<br>Daikin<br>Blue Star<br>Voltas<br>Hitachi<br>Stulz<br>LG |

| | | |
|---|---|---|
| | | Mitsubishi<br>Toshiba<br>Samsung |
| **TUNNEL AUTOMATION & SCADA SYSTEM** | | |
| 35 | PLC and SCADA System, FO cables and accessories, Cabinets, Cat-6 Armoured FTP, Cat-6 Patch Cord, Fiber Terminations | ABB<br>Schneider<br>Siemens<br>L&T<br>Rockwell<br>Panduit<br>Pyrotech<br>Siemens<br>Honeywell<br>Legrand<br>Finolex<br>Lapp<br>Polycab<br>Molex<br>Aksh<br>Cisco<br>TC communications<br>Tyco |
| 36 | Lighting Sensors, Control & Automation | Schneider<br>Helver<br>Lutron<br>Honeywell<br>Bajaj<br>Siemens |
| **LIGHTING, PA, CCTV SYSTEM** | | |
| 37 | Video Management Software, CCTV Camera, | PELCO<br>BOSCH<br>AXIS<br>Philips<br>Siemens<br>Schneider |
| 38 | Workstation and Monitor | HP<br>DELL<br>HCL<br>Siemens<br>Honeywell<br>Schneider |

| | | |
|---|---|---|
| 39 | Speaker, Radio system, Voice Alarm controller, Amplifier, IP phones | Bosch<br>Ateis<br>SystemSensor<br>Motorola<br>Zenitel<br>Commend<br>Schneider |
| 40 | High pressure Sodium Lamp, Fluorescent Lamps | Philips<br>Osram<br>Bajaj |
| 41 | LED Lighting Fixtures | Philips<br>Wipro<br>Osram<br>Bajaj<br>Thorn<br>Surya<br>Syska |
| 42 | Door contact, Plug Socket, Telephone Socket, Switches | EAZ<br>Legrand<br>Havels<br>Crabtree<br>Hensel<br>Schneider<br>L&T<br>Spelsberg<br>Cap electric<br>BCH<br>Clipsal<br>Panasonic<br>Hager<br>ABB |
| **Miscellaneous** | | |
| 43 | Junction Box | Hensel<br>Legrand |
| 44 | Potential Equalization Connections, Galvanized Steel & Copper, Galvanized Steel Ropes | Pipe Life<br>Meinhart<br>Obo-Bettermann<br>SY Systems<br>Erico |

| | | |
|---|---|---|
| | | Easyflex<br>JMV<br>Indelec |
| 45 | Earthing System | JMV LPS Ltd<br>Erico<br>Furse(ABB)<br>Indelec<br>Obo-Bettermann<br>Macronite |
| 46 | Industrial Switches, Routers, Media Converters, Uplink Modules & Modems | Cisco<br>Schneider<br>Siemens<br>TCCommunications<br>Tyco<br>D-link<br>HP<br>Alcatel<br>Allied Telesis |
| 47 | Enclosure, Rack & Patch Panels, Containment | Netgear<br>Schneider<br>APC<br>Korenix<br>Globe<br>Indiana<br>Profab<br>Engineer<br>Rittal<br>Valrack |
| 48 | Paints | AsianPaints<br>Berger<br>ICI<br>ShalimarPaints<br>Johnson & Nicolas<br>Nerolac |
| 49 | Mannhole Covers and frames, CILA Fittings | Raj Iron Foundry<br>Kartar Valves and Fittings<br>Neco<br>Electrosteel |
| 50 | Lightning Protection System | JMV LPS Ltd<br>Furse<br>Erico<br>Indelec |

| | | |
|---|---|---|
| | | OBO-Bettermann |
| 51 | Signages | Illumination Enterprise<br>3M<br>Local & approved |

# Section 8

# TUNNEL VENTILATION AND FIRE FIGHTING SYSTEMS

## 8.1. Tunnel Ventilation System

### 8.1.1. General Context

This section of the document describes the design, supply, manufacture, delivery, erection, operational maintenance, testing and commissioning of the Tunnel Ventilation Systems for the tunnels.

The purpose of the ventilation system is to ensure the safety of all persons who travel through the tunnel from harmful levels of vehicle emissions. Pollution measurement sensors will be installed throughout the tunnel, which will measure the intensity of gases present. The pollution level will determine when to activate the tunnel ventilation system to force out the harmful gases.

Tunnel ventilation systems should provide adequate in-tunnel air quality during normal and congested traffic operations and support the self-evacuation and rescue efforts during emergency incidents. Separately, the tunnel ventilation capacity requirements for emergency ventilation (typically for the control of smoke and hot gases during fire) must also be assessed and the system designed accordingly. Therefore, the ventilation system works for the following two modes:

- During normal operation of the tunnel
- During fire inside the tunnel.

The following general factors shall be considered during the ventilation system design:

1. Length of the tunnels (main tunnel and the entry and exit tunnels)
2. Cross section (width and height) of the tunnels.
3. Type of traffic
4. Fire safety

a. Presence of emergency exits

b. Change in the direction of fans

5. Cost and Environmental issues

a. Energy consumption

b. Localized and concentrated emission of polluted air from portals and stacks.

### 8.1.2. Tunnel ventilation during normal operation

The tunnel ventilation during normal operation should include estimation of pollutant load and estimation of fresh air requirement

1. Estimation of pollutant load

The estimation of total emission rate or pollutant load inside the underground tunnel shall be based on analysis of alignment to decide sections, and analysis of number of vehicles.

The following input parameters shall be considered for the estimation of pollutant load in terms of emission rates for each section of the tunnel:

a. Length of the tunnel/section

b. Road gradient or slope

c. Tunnel altitude

d. No. of different types of vehicles passing through the tunnel per hour. The vehicles mainly include, passenger car units (PCU), light commercial vehicle (LCV), heavy commercial vehicle (HCV), heavy goods vehicle (HGV), electric vehicles (EV)

e. Speed of the vehicles. The speed of the vehicles will be different for different traffic conditions, normal and congested ones.

f. Parameter influencing the power needed to propel the vehicle such as average mass of the HGV vehicle

g. Pollutant concentration in fresh air/ fresh air quality

2. Estimation of fresh air requirement

The fresh air requirement is based on the maintaining of admissible air quality. The air quality shall be measured in terms of concentration levels of gases CO, NOx and particulate matter (PM) deciding the visibility. Estimation of fresh air requirement should adhere to the requirement of threshold values associated with these elements.

a. Design values for CO:

The concentration of CO should not exceed 70 ppm during normal traffic and may permitted to have 100 ppm during congestion. Above 200 ppm, the tunnel operations shall be suspended

b. Design values for NOx:

NO by itself is not considered a harmful pollutant at commonly encountered levels. On the other hand, NO2 is noxious and can irritate the lungs and lower the resistance to respiratory infections such as influenza. A permissible average in-tunnel concentration of 1.0 ppm NO2 along the length of the tunnel at any one time shall be considered as the design value.

c. Design values for particulate matter (PM):

The presence of particulates leads to reduced visibility inside the tunnel. Therefore, visibility criteria are intended to support the ability of a driver to stop safely. The tunnel ventilation system must provide visibility levels that exceed the minimum vehicle stopping distance at the design speed.

The extinction coefficient K (1/m) expresses the tunnel visibility, the different visibility conditions considered for ventilation design are based on extinction coefficients 0.003 $m^{-1}$, 0.007 $m^{-1}$, 0.009 $m^{-1}$ and 0.012 $m^{-1}$ are slightly hazy, hazy, foggy and uncomfortable respectively.

For the present tender design, the maximum fresh air requirement for normal operation is 331 $m^3/s$.

**Extent of Work**

The work under tunnel ventilation system shall include the

• Axial and Jet Fans.

• Motorized Fire Dampers.

• Sound Attenuation.

• In- Tunnel and External Environmental Sensors and Monitoring Equipment. In addition, the extent of work shall include, but is not necessarily limited to:

• Interfacing with power supply systems, central monitoring & control system, fire services and

traffic control surveillance system.

• Preparation of technical calculations to demonstrate ventilation system performance to meet

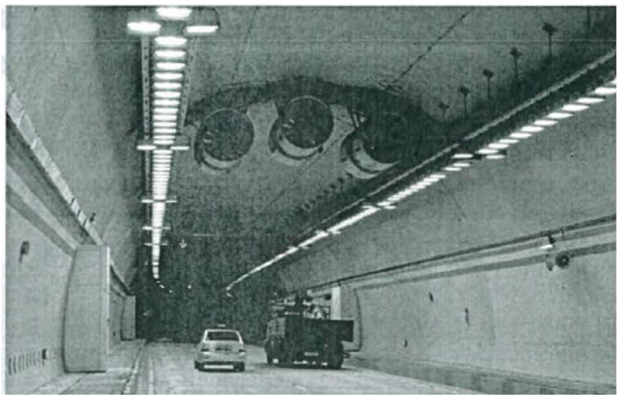
environmental criteria and fire scenario.

• Preparation of control specification for axial/jet fans based on traffic flow, traffic speed and

pollutant levels.

• Preparation of emergency operation procedures for tunnel ventilation system.

For each system, a complete commissioned, balanced and tested installation with Shop Drawings, As built drawings, Operation and Maintenance Manuals, Factory Acceptance Tests and Site Acceptance Tests shall be taken into account.



**Jet Fans Installed in a Road Tunnel with Longitudinal Ventilation System**

In addition to the main scope of work, the Concessionaire shall also allow for the following work:

• Provision of terminal Cubical for connection to the Power Supply System cabling.

• Provision of terminal cubicle for connection to the Central Monitoring and Control System; Traffic Control and Surveillance System; apd Fire Services System cabling.

• Allow for filling all holes left in floors and walls to Council and Authorities standards and fire requirements.

**Work By Other Trades**

**M&E Fire Systems Works**

Provision of all fire detection and suppression systems associated with the tunnel.

**M&E Electrical Systems Works**

Provision of all Electrical Systems including HV & LV supply and distribution systems, and lighting systems.

Provision of Control Systems including Integrated Tunnel Controls Systems (ITCS), Plant Management and Control Systems (PMCS) and Traffic Management and Controls Systems (TMCS).

**Underground Bulk Diesel Fuel Tank and associated Transfer Pumping System Works**

Provision of Underground Bulk Diesel Fuel Tank and associated Transfer Pumping System, including backfilling.

**HVAC Services Works**

Provision of all Axial Fans, Dampers, Silencers, Ductwork and Controls system related to the North and South Portals and Mid-Vent shafts.

**Tunnel Operational Vehicles**

Provision of maintenance vehicles, emergency response-vehicles.

**Design Criteria**

To ensure that the ventilation system and its associated equipment meet the requirements of IRC SP-91-2019, PIARC and NFPA.

To ensure that the ventilation system can control the movement of smoke from a fire with a peak heat release rate of 50MW while an adverse pressure of 15Pa is acting on the exit portal.

To install an effective, versatile and energy efficient ventilation system that reduces· the time and cost spent on maintenance.

To reduce the risk of incorrect operation of the ventilation system in an incident involving fire

To ensure required air quality and visibility levels are maintained.

To provide adequate tunnel ventilation during tunnel maintenance closures.

Jet-fans located close to the fire has to be deactivated to compensate for the loss in momentum.

Pressurization axial jet fans shall be installed inside each cross passage at about mid-length.

The two types of ventilation systems used separately or in combination are as linear system and transverse system. In this case as both the tubes are unidirectional with ventilation shafts provided at either ends, linear system of ventilation shall be adopted.

It is proposed to reject all vehicles carrying flammable and dangerous goods on entire section of the tunnel during peak traffic times. This is to eliminate risk of such vehicle entering in to tunnels and getting involved in an accident. Such type of vehicles may cause fires of up to 1 OOMW having disastrous effect on tunnel structure. Based on present traffic volumes the HGV percentage is likely to be Jess than 5% of overall traffic volume. Hence a 50MW fire (BD 78/99 table 8.2) is adopted for design of ventilation to bring the impact to an acceptable level.

The tunnel ventilation sy.stem shall be designed to protect passengers upstream of the fire site and to provide a smoke clear evacuation path for passengers to escape and for rescue personnel to approach the fire site.

The maximum air velocity inside the tunnel due- to the ventilation system shall not exceed 10 m/s to permit passengers to safely walk in the tunnel during an emergency event.

The main tunnel ventilation equipmen~ is required to handle hot smoke during a fire emergency and shall be rated for 400 deg C for 2 hours.

The design life of all mechanical plant i,n this specification shall be 20 years.

The ventilation system in each bore can be controlled .. either automatically via the Integrated Tunnel Control System (ITCS) computer located in the Control buildings, or manually from the relevant Ventilation Control Panel in the LV Switch room.

Control of the fans is normally initiated automatically in response to increasing carbon Monoxide (CO), Oxides of Nitrogen (NOx) or poor visibility. Air Monitoring stations are located at the ends of the tunnel and mid points.

### 8.1.3. Tunnel ventilation during fire inside the tunnel

1. Tunnel ventilation during fire inside the tunnel shall include the choice of maximum heat load and design fire curve, selection of ventilation system, design and dimensioning of the system and design of firefighting systems.

2. The range of maximum heat release rate shall be considered as 1.5 - 300 MW, and the range of smoke release rate shall be 20 - 300 $m^3/s$. In addition to the requirement of supplying fresh air in the normal operating conditions the ventilation system should consider the following aspects to handle fires in tunnels:

a. The required tunnel air velocity during this scenario shall be more than the critical velocity required to avoid the back layering (flow of smoke upstream of the fire).

b. The heat release rate for the design shall be considered as 30 MW.

### 8.1.4. Tunnel air quality and visibility measurement system

1. The operational ventilation inside the tunnel shall be managed by monitoring the tunnel air quality. This shall be managed through the tunnel measurement system which consists of measurement of visibility affected by dusty environment, measurement of CO and NOx emissions, flow velocity and direction measurement and temperature measurement etc.

2. The visibility sensors shall comprise of transmitter (TX) and receiver (RX) which work on the principle of a single pass light transmission system also known as optical measurement principle. The TX emits a visible (green) optical beam which is received by the RX. Any dust or smoke particles present will attenuate the light beam and cause the intensity of the light received by the RX to fall. This reduction in light intensity is used to determine visibility in the tunnel. The visibility criterion is mentioned in the normal operations above.

3. The tunnel air quality shall be monitored through the electrochemical cell technology to determine CO, NO & NO2 concentrations.

4. The ultrasonic airflow measurement technology shall be used in tunnels to measure the air flow velocity and direction. With no moving parts, the system requires minimal servicing and can be fully sealed from the tunnel's harsh environment. Measurements are independent of temperature, pressure and composition of the tunnel atmosphere. Other than a regular clean and check, it can be considered a 'fit and forget' solution. The two transducers shall be installed on the both walls of the tunnel in an angle of $45^0$ to driving direction and shall work as sender and receiver alternately to determine the air flow speed and direction.

5. These sensors shall be positioned on the tunnel walls in equal distances to each other. The distance between air quality and visibility sensors shall be two times than the distance between the two air quality sensors and three times for air velocity and direction measurement sensors.

6. This system shall be connected to SCADA system through PLC and sensor measurements shall be provided through UPS.

7. Technical specification

a. The design materials shall be epoxy coated aluminium housing sealed to IP65

b. The measuring units shall be ppm for CO & NO, m-1 or m for visibility

c. The response time for CO shall be 2mins, for NO shall be 2 mins and for visibility shall be 10s to 2min. Device shall be rated for 20°C to +50°C temperatures.

8. The typical representative image and the corresponding drawing of the air quality and visibility measurement unit is shown below

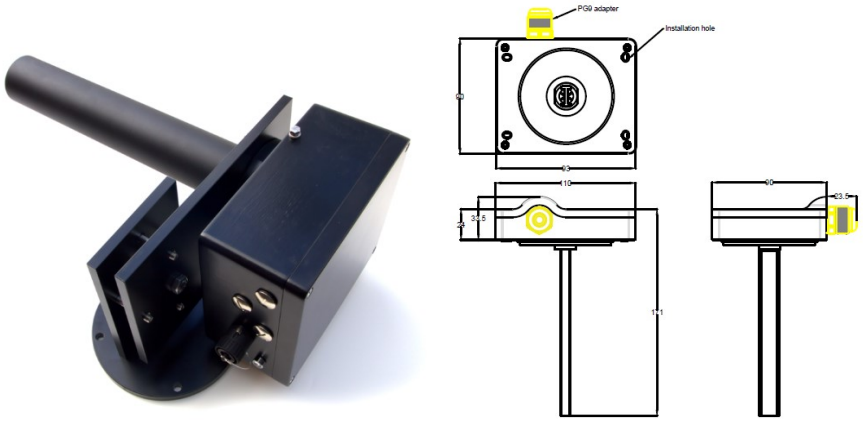



Figure 8.1: Air monitoring system

### 8.1.5. Ventilation system types

1. Fully transverse type Mechanical Ventilation system shall be provided inside the main tunnel tubes.

2. Duct and damper dimensions

a. The fresh and exhaust air ducts of sizes 12.5 $m^2$ each shall be installed above the tunnel vehicular area by constructing 25-30 cm thick concrete ceiling. These ducts shall be separated from each other. The ducts sizing both in main tunnel section and in cut and cover sections shall be adjusted based on the total volume available above the tunnel vehicular area.

b. Appropriate jet fans shall be installed inside the duct above the vehicular tunnel areas and inside the shafts located at portals. The fresh air injection sizing shall be based on the fresh air supply. The fresh air openings of size 2.4 $m^2$ shall be provided for each 115 m distance. The extractor openings shall be provided with dampers. The maximum sizing shall be based on the fresh air and smoke flow rate, which shall be higher than the sizing of the fresh

air openings. The typical extractor sizing shall be 60% more than the fresh air vent sizing (4 $m^2$). The opening through extractors shall be adjusted by operating the dampers according to normal and fire scenarios.

c. These fresh air vents and extractors shall be operated through actuators and shall remain open during normal operations. Actuators shall be operated automatically as soon as fire is detected, to adjust the vents openings and dampers in extractors.

d. During the fire scenarios, the fresh air vents in the distance of around 100 m from fire location shall be closed. The extractors in these regions shall be fully opened by adjusting the dampers, to remove the additional flow rate generated by smoke.

3. Fan technical specification

4. The design materials shall be selected to avoid galvanic and other corrosion of any jet fan fixings. A minimum material 304 or 316 stainless steel as per IS 6911: 1992 shall be used in tunnel. The jet fans shall be mounted with the suspension system, vibration sensor, anti-condensation heater, and dynamic balancing.

5. The traditional jet fans shall be made of carbon steel material (S-275 JR) having aluminium alloy blades for impellers. Also, the capacity shall be 90000 cmh and static pressure as 500 Pa. The fan area shall be 0.79 $m^2$ and power requirement shall be 30 kW.

6. Jet fan shall be reversible, and operating voltage shall be 415 V

7. The different parts of the jet fans, including construction and cabling (from fan to junction box) shall be designed to resist temperatures up to 250°C for 120 minutes. Fire test certificates provided by manufacturer shall be furnished to establish the withstand temperature and time parameters.

8. The detailed fan specification is given below:

| **Sr. no.** | **Description** | **unit** | **Specification** |
|---|---|---|---|
| Jet fan | | | |
| 1 | Diameter of the fan | mm | 1000 |
| 2 | Overall length | mm | 5000 |
| 3 | Maximum distance from the ceiling | mm | 1000 |
| 4 | fan flow rate | cmh | 90000 |
| 5 | Installation factor | | 0.8 |
| 6 | Maximum noise level | dBA | 95 |
| 7 | Jet fan type | | Reversible with silencers |
| 8 | Blade material | | Aluminum alloy |
| 9 | Shaft material | | carbon steel material (S-275 JR) |
| 10 | Fan casting material | | carbon steel material (S-275 JR) |
| 11 | Fan test arrangement | | ISO13350 |
| 12 | Thermal rating | | F250 |
| Fan motor | | | |
| 1 | Motor type | | 3 phase induction |
| 2 | Voltage | V | 415 |

| | | | |
|---|---|---|---|
| 3 | Normal running current | A | By bidder |
| 4 | Frequency converter | | YES |
| 5 | Minimum motor efficiency | % | 70 |
| 6 | Shaft Power | kW | 30 |
| 7 | Thermal rating | | F250 |
| 8 | Protection class | | IP65 and higher |
| 9 | Motor finish | | Epoxy |
| Accessories | | | |
| 1 | Temperature elements for each bearing | | PT100 |
| 2 | Temperature elements for each winding | | PT100 |

a. The typical representative image of the fan and its drawing is shown below.

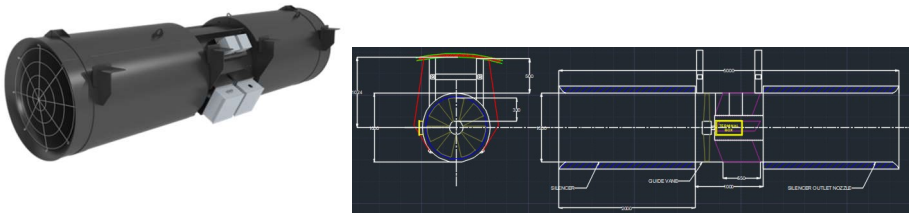


Figure 8.2: Jet fan

9. Fan positioning

a. A pair of jet fans shall be mounted inside both fresh and exhaust air ducts. The positioning of fans shall be decided based on the total air flow requirement, fan capacity and number of fans required for the same.

b. Traditional jet fans shall be positioned at every 115 m. The typical cross section of the tunnel indicating the duct sizing and fans positions shall follow the design given below.

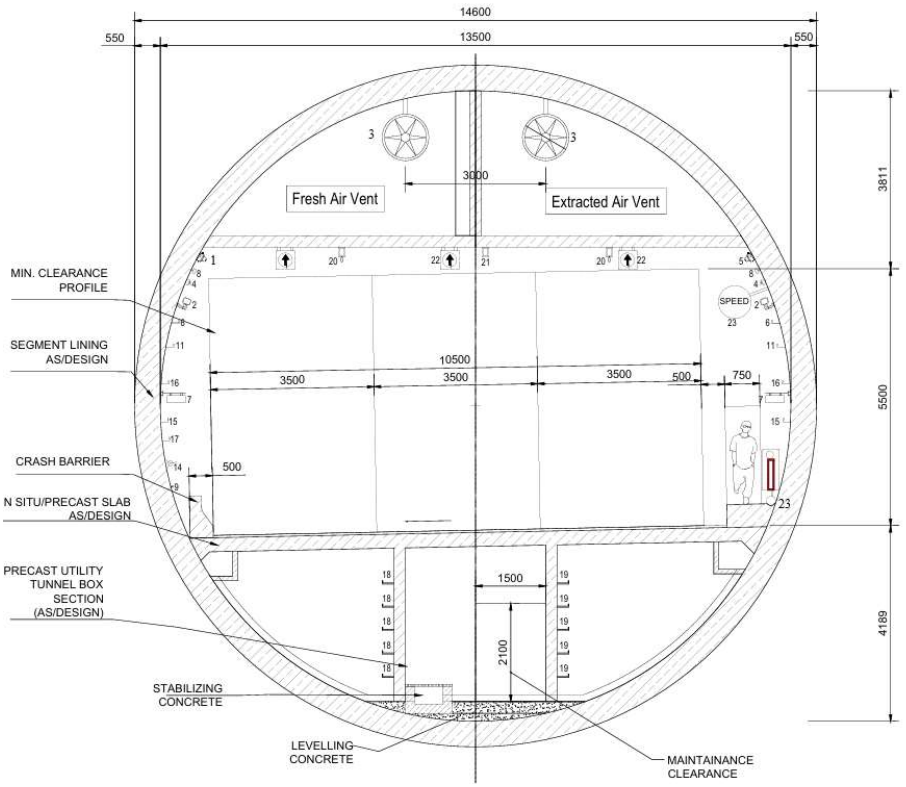



Figure 8.3: Cross section of the main tunnel showing duct and fans positioning

c. Fans shall be positioned at same places during both normal and fire scenarios. Only the capacity of fans shall be altered based on the additional smoke flow rate. The smoke flow rate shall be designed corresponding to 30 MW fire rating 50 $m^3/s$.

d. The jet fans shall be installed in the main tunnel tubes as per drawings. The jet fans in the main tunnel shall not affect the safe operation of traffic. These fans shall not be affected by other tunnel installations. The lighting system of the main tunnel and other ceiling mounted installations shall not be affected by the operation of jet fans. The structural assembly of jet fans fixing arrangements on tunnel walls/ceilings shall be designed keeping in view the water lining of tunnel wall and shall be got approved, prior to taking up execution.

e. The complete construction, including safety restraints, shall be mounted and installed at the ceiling with stud bolts (tension and pressure). The different connections (specific dimensions of screws and bolts) of the jet fans including mounting frame etc. shall be adapted to the specific static and dynamic loads which occur in the tunnel (normal and emergency operation).

10. Additional considerations

The jet fans shall be selected such that they work at least 120 minutes with hot air ($250^0$C) and smoke. Jet fans shall be provided with fail safe anti-vibration mountings to prevent the fans falling onto traffic in the event of the failure of a fixing.

The complete construction has to be manufactured and installed considering the actual state-of-the-art technology. The construction shall be robust, simple and convenient for use in road tunnels. Further the complete construction (materials) has to withstand particle, humidity and the occurring aggressive tunnel atmosphere.

11. Spacing requirement at portal and inside the shaft

At the end of each tunnel section, the portal of size 100 m X 50 m shall be designed. In these portals the spacing for two fresh air and exhaust ducts shall be provided to accommodate the flow exchange from the two tunnels. The typical sizing for each fresh and exhaust air duct shall be 30 $m^2$ and 25 $m^2$ respectively. These shall be positioned at the corners of the portals. Schematic for the possible positioning is shown below.

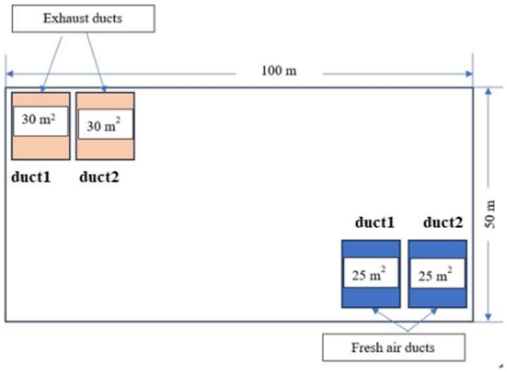



Figure 8.4: Duct sizing and positioning at the portals

12. Power requirement and functioning of the ventilation system

a. Most of the power requirements in ventilation system belongs to the fan operations and associated equipment's such as dampers. Total estimated power requirement for operating each fan with 90000 cmh is 22.5 MW. Additional 30 % of power shall be considered for operating the fire safety equipment's. Total power requirement shall be 30 MW

b. The ventilation system monitored and controlled through the SCADA system. The jet fans shall be fully reversible and shall be operated at different speeds through PLC, which is connected to SCADA system, in accordance with the functional protocol. All the signals for forward start, reverse start and to stop to the jet fans shall be supplied through the PLC. SCADA system shall monitor the air quality and fire scenarios and accordingly the jet fans will be operated to provide the required flow rate. The PLC system shall provide the status of the fan such as the motor run status, its speed etc. The fans can be switched on as required from the PLC to adjust the system performance to the p-articular necessities, i.e., light traffic hours, peak hours, emergency, etc. with forward start, reverse start and stop functions.

c. All the necessary control equipment will be provided including all relays, transformers, manual switches, controllers, dampers, motors, wiring and all accessories necessary to perform the intended function of the system.

d. The Tunnel Ventilation system will be controlled and monitored by the Integrated Tunnel Control System having central computer system (CCS) for the same, which will be supplied and installed by others. The CSS shall receive data from the tunnel environmental sensors and traffic surveillance system to control the fans.

## 8.2. Firefighting equipment

According to the latest guidelines for Road Tunnels published by the Indian Roads Congress (IRC), the firefighting system of the tunnels shall be equipped with:

- Automatic fire detection systems
- Hand – Operated Fire Extinguishers
- Fire Hydrants
- Hose Coil with Supply
- Water Reservoir
- Sprinklers
- Fire pumps

### 8.2.1. Automatic fire detection system

a. Fire detection systems shall include detectors of heat (temperature and rate of rise), smoke, and flame. In addition, there shall be spot and linear heat detectors. LHD shall be used in the tunnel and spot detectors shall be used inside the duct too. Automatic fire detection systems shall be capable of identifying the location of the fire within 15 m (50 ft). Automatic fire detection systems shall be able to detect a tunnel fire incident of 5 MW or less within 90 seconds or better in a testing environment of 3 m/sec (590 fpm) air velocity. Fire alarms shall to be placed at every 100 m which are inline with other firefighting equipment, while the fire alarm sensor shall be at every 20 m as per section 7.4.6.6.4 of NFPA502. This shall meet the requirements of both the standards and permits some redundancies.

b. The LHD shall have the Fixed temperature set point or rate of rise temp setting with Programmable alarm. The operating temperature shall be in the range of -20 degree to 70 degree with alarms for open circuit and short circuit. The standard fixtures shall be duly approved by LPCB / EN54. The typical LHD representation is shown below.

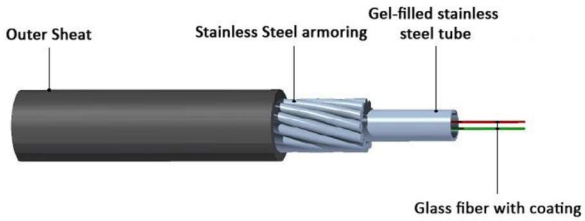



Figure 8.5: Linear heat detector

c. The fire alarm unit shall have EN54 approved fire alarm control panel, which shall be expandable, networkable, having option to interface to BMS with optional interface of LON Works, BAC net & MOD Bus, with a battery backup of 24hrs in normal condition and 30min in alarm condition. It shall have multi sensor with optical smoke element and thermal element. The fire detector shall have facility to mount in different comprehensive places as required and duly approved by LPCB / EN54. The typical fire alarm panel is shown below.

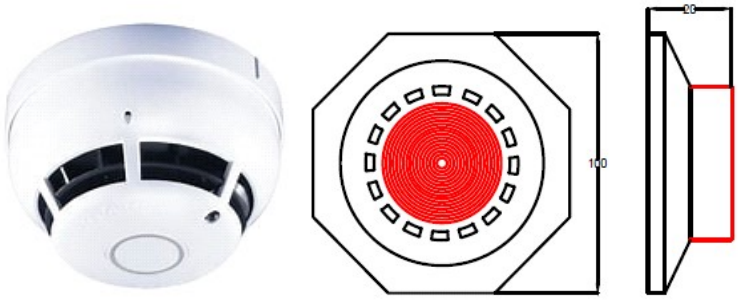


Figure 8.6: Fire alarm system

### 8.2.2. Hand – Operated Fire Extinguishers

The fire extinguishers shall have a minimum content of 6 kg. They shall be rated for liquid, grease and electrical equipment fires. These shall be installed at every 90 meters. The removal of it shall trigger an alarm to the SCADA system. Additional extinguishers shall be provided in the portals. The typical fire extinguisher is shown below.

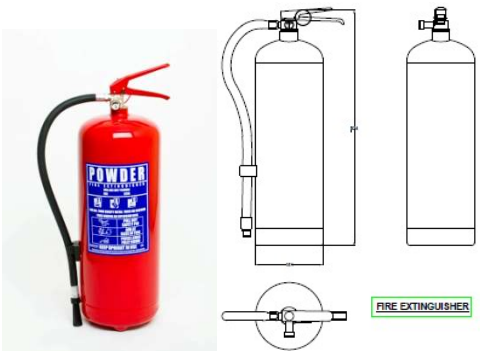



Figure 8.7: Fire extinguisher

Portable extinguishers shall:

• be rechargeable

• be hand operated

• comply with relevant standards

• be of approved manufacture

• be acceptable to the Fire Authority

• be of the type. and size as scheduled or as shown on the tender drawings Volume-Ill: Schedules.

### 8.2.3. Fire Hydrants

a. It is recommended that all road tunnels of sufficient length (200 to 1000 m according to the case) shall be provided with a water supply standpipe installed through the length of the tunnel. This standpipe shall have a minimum capacity of 1000 l/min at 0.5 MPa (PIARC, report 05.05.B, 1999, section 6.3.3.3). The standpipes are wet type. Hydrants should be placed at a spacing of 50 m. The fire main and hydrants shall be placed in such way that the walkway width remains clear of this. The connections between the main tube sections and entry/exit ramps are possible through the utility spacings. It can also be carried out using hose bridge on connectors. The utility spacing is also provided to connect the standpipes between cross-passage and main tunnel section. The appropriate sealing will be used to avoid the depressurization, and this shall be carried out by the concessionaire during the detailed design place.

b. The typical output connection shall have sizing of 2 x 2 ½'' + 1 x 4'' and assembly depth shall be of size 550 mm. The fire hydrant shall be of type C (according to EN 14384 standard) with anti-icing system, helical spring closure. It shall have nominal pressure as 16 bar.

c. The typical fire hydrant is shown below.



Figure 8.8: Fire hydrant

### 8.2.4. Hose connections

These shall be placed at every 50 m along with fire hydrants and shall be made up of case aluminium alloy material. These shall have diameter of 100 m and designed for 23 kgf/cm$^2$ pressure. Typical hose pipes are shown below.

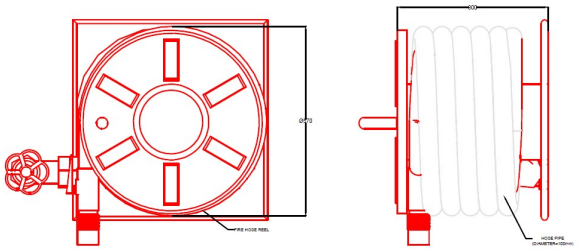


Figure 8.9: Hose pipes

### 8.2.5. Water reservoir

The total capacity of the water tank shall be sufficient to provide water supply for 60 minutes of operation. This shall have a minimum capacity of 60000 l. The tanks shall be placed closed to the pump room and shall be built at ventilation stations. The water level shall be monitored using SCADA system and in the event of drop in the level of it below the required one, it shall trigger an alarm.

### 8.2.6. Sprinkler system

a. The sprinkler systems shall have a type of fixed fire suppression system (FFS) that can be used in tunnels to help prevent fire spread and cool the tunnel structure. The sprinkler arrangement shall be used at every 4 m

b. The sprinkler system shall have bove ground pipes of type MS pipes "C" class with pressure rating as 11Kg/cm2 for 8 hours. The diameter of pipes shall be 200 mm, 100 mm, 32 mm, and 25 mm

c. The sprinkler bulbs shall be of 15mm diameter nominal bore quartzoid type. These shall have the temperature rating of 68 / 93 deg C of K-80 factor and shall have a pendant type of 93 deg C.

d. The typical system bulb is shown below.

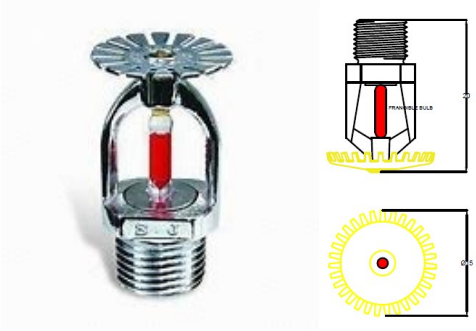


Figure 8.10: Sprinkler system bulb

Portable extinguishers shall:

• be rechargeable

• be hand operated

• comply with relevant standards

• be of approved manufacture

• be acceptable to the Fire Authority

• be of the type. and size as scheduled or as shown on the tender drawings Volume-Ill: Schedules .

### 8.2.7. Fire pumps

The three equipment shall be provided in the fire pump rooms, main pump, standby pump-diesel engine driven, and jockey pump. There specification is given as follows:

1) Electric Pump:

- Axial suction, radial impulsion
- Stainless steel shaft
- 4660 lt/min, head of 350 m rated 2900 rpm
- 2 poles three-phase asynchronous motor (415 V, 50 Hz)
- Protection: IP55
- Power: 150 kW
- Pressure range 3.5 kg/cm2 at the farthest sprinkler/hydrant point

2) Diesel Pump:

- Horizontal centrifugal end suction type
- 4660 lt/min, head of 350 m rated 2900 rpm
- CI casing, CI impeller.

The diesel engine shall be naturally aspirated (non-turbocharged) and electrically started. The engine shall have a speed governor to regulate the rated rpm within 5 % of its rated speed. The engine shall be complete with starting batteries full-wave selenium rectifier charger, isolator, leads, mounting frame etc. Engine rating shall be same as for the electric motor. Pumps and prime movers shall be truly aligned by suitable instruments. Entrepreneur shall provide necessary test certificates, performance curves of all the pumps. All the pumps shall be provided with approved type of Mechanical seals. On the suction and delivery lines, double flanged reinforced neoprene flexible connectors shall be provided.

3) Auxiliary Jockey Pump:

- Vertical Multi in line type fire pump
- 2900 RPM capable of delivering 460 lts/min against a head of 350 m.
- 415V, 3phase, 50Hz

- Bronze impeller
- Power: 1.5 kW
- Protection: IP55
- Shaft isolation with mechanical closure

The jockey pump shall start automatically on the detection of loss of line pressure. Upon continuous pressure loss, the main fire pump shall start automatically and take over the pumping. The motor starters (direct on line or star-delta) shall consist of electrically actuated contactors. The starter shall be complete with ON-OFF push buttons, timers and auxiliary contacts and shall be fully automatic. There shall be an indicating lamp with each of the pumps and an ammeter and selector switch with the fire pumps. Fire pump starting shall be done through the MFACP. A remote start stop facility shall be provided in the Fire Control Room.

4) General considerations

The hydrant pumping systems shall maintain their respective delivery lines pressurized at all times for firefighting and wash-down. The impeller shall be statically and dynamically balanced after assembly into the shaft. The pumps shall comply in all respects to the requirements of the relevant standard. Each system comprises two equal size pumping unit, one duty and one standby. · Each station has been provided with a bypass valve for pump running test without interrupting the hydrant systems. The pumps shall have soft starters in order to minimise the impact of water hammer and to reduce the motor starting currents. The pump shall be sized to allow for a 1 0% upgrading of the maximum impeller size. Packing shall be coated with graphite grease before insertion. The shaft shall be fitted with renewable bronze wearing sleeves for the gland seal. Pumps shall incorporate drip wells and screwed outlets under the exposed ends of the glands. Copper drain pipework shall be run from each drip well to discharge over the nearest waste point.

Each pump and motor assembly shall be mounted on a common base of substantial mild steel or cast iron construction of adequate strength to maintain the components in correct alignment.

An identification plate of either brass or aluminium shall be screw fixed to the pump unit and shall include but not be limited to the following information:

• manufacturer

• model

• serial number

• size

• impeller rpm

• impeller size mm

• packing and spacers make/size/catalogue number ·

• pump rating# litres/sec.

• orifice plate details, if used.

If a hydrant point is opened, the jockey pump would start first because of the pressure drop. Since the demand of hydrant point cannot be catered by a jockey pump, the main pump would start. The control arrangement will be provided such that when main pump start, the jockey pump is cut off. In case the main pump fails to start, the standby pump set would come into operation

The typical pump arrangements is shown in the following figure.



Figure 8.10: Pumping station

## 8.3. Safe evacuation during emergency operation

a. The Cross passages shall be placed at every 500 m for the safe evacuation of the passengers in the emergency event. The pressurization of the escape routes shall be done such that the smoke does not enter these regions from the tunnel with fire (Typical value is 50 Pa and a velocity of about 2m/s)

b. To avoid fire spreading of fire inside cross passages the door frame, shall be designed to resist fire for at least a 1 or 2 hours of fire exposure. The double fire check door made up of steel (Grade St 32.0 of IS: 1977- 1962) material shall be installed in each cross-passage openings to both the tunnels. The door frame shall be at least 6 mm thick and shall be installed with hinge type support. The doors shall be of the size of 4.5 m X 4 m

c. The signage boards indicating the "FIRE EXTINGUISHER" shall be installed near the fire extinguishers (every 90 m) to indicate the same. The other signage boards such as "ASSEMBLY POINT" and "MANUAL CALL POINT" shall be appropriately placed between the cross-passages and at the emergency phone locations respectively. These boards shall be of the size of 150 mm X 150 mm, made up of luminescent safely, rigid green coloured sheet. These samples shall be approved by the Architect before procuring the same.

## 8.4. Codes and guidelines:

Following Indian and international codes and guidelines shall be considered for the ventilation system design and for fire-fighting equipment's specification:1

1. B SMILE, Request for Proposal for the "Consultancy services for preparation of DPR for the work of Construction of Underground Vehicular Tunnel from Hebbal Esteem mall junction to Silk Board KSRP junction", 2024.

2. IRC, Guidelines for Road Tunnels, IRC: SP-91-2019, 2019.

3. Maevski, I, Guidelines for Emergency Ventilation Smoke Control in Roadway Tunnels, NCHRP Research Report 836, 2017.

4. PIARC, Design Fire Characteristics for Road Tunnels, Report 2017R01EN, 2017.

5. PIARC, Fire and Smoke Control in Road Tunnels, Report 05.05.B, 1999.

6. PIARC, Road Tunnels: Vehicle Emissions and Air Demand for Ventilation, 2019R02EN, 2019.

7. PIARC, Vehicle Emissions, Air Demand, Environment, Longitudinal Ventilation, Report 05-02-B, 1995.

8. Directive 2004/54/EC: Minimum safety requirements for tunnels in the Trans-European Road Network

## Section-9

## ADVANCED TRAFFIC MANAGEMENT SYSTEMS (ATMS)

The following Specifications and Standards shall be applied in addition to 'Manual on Specifications and Standards for Tunnels' published as IRC: SP: 99-2013 with all

amendments and additions till date.

### 1. Advanced Traffic Management Systems (ATMS)

### 1.1 General

The work would cover design, supply, installation, commissioning and/or operation and maintenance of Advance Traffic Management Systems (which is one of the components of Intelligent Transport Systems- ITS). The system would include out-door equipment including emergency call boxes, variable message sign systems, meteorological data system, close circuit TV camera (CCTV) system, traffic counting and classification system and transmission system. The indoor equipment would comprise a large display board, central computer (with Network Management System- NMS), CCTV monitor system, call center system or management of emergency call boxes housed in a control center with uninterrupted power supply. Any new technology, meeting the requirements specified in these specifications. should not be excluded. The systems shall meet the following objectives:

- Smooth and uninterrupted traffic flow
- Enhance road safety
- Real time information and guidance to users
- Emergency assistance round the clock
- Alerts for abnormal road and weather conditions
- Reduced journey time and inconvenience

### 1.2 System Requirement

ATMS shall provide the following facilities to Tunnel users:

- make emergency calls to Control Centre in case of accidents, breakdown, fire and ambulance.
- pre-warn the Tunnel users about unusual conditions on the road.

ATMS shall provide the following information/data to traffic managers for efficient and effective handling of traffic.

- information regarding location of any incident, incoming calls, help required and messages to be passed to third parties.
- Information regarding traffic congestion, speed and weather conditions.

ATMS shall provide the following controls to traffic managers:

- change the variable message signs from the Control Centre.
- mobilize the movement of ambulances, cranes & patrolling vehicles.

ATMS shall provide online recording and reviewing of the voice & visual information for record and analysis.

Value Added Systems in information dissemination to users of the Project may be taken up in future. These shall include the following:

(i) Value Added Systems in the form of real time information on traffic conditions, unusual events, congestion levels, weather conditions etc.; to facilitate project users as also the operator.

(ii) Through relevant websites including that for the Project SPV/Concessionaire

(iii) Subscription based alert systems

(iv) Dedicated TV channels pertaining to traffic movement

*(v)* Tie ups with FM radio channels or creation of dedicated AM radio channel

(vi) Dedicated Toll-Free Telephone Systems

Note: Local language is emphasized in *the above* systems.

The ATMS shall among many things comprise the following sub-systems:

i. Communication backbone

ii. Emergency Communication System

iii. Mobile Communication System

iv. Variable Message Sign System

*v.* Meteorological Data System

*vi.* Automatic traffic counter-cum-classifier system vii. Video Surveillance System

viii. Video Incident Detection System (VIDS)

ix. Central Control Room (CCR)

x. Weigh in motion for axle load measurement

xi. Power Supply System

These systems shall have outdoor equipment consisting of ECBs, VMS panels, weather sensors, traffic sensors, video camera etc. The outdoor equipment shall be connected to the control centre through a transmission system preferably comprising optical fibre cable, copper cable and interface equipment. There shall be one control centre per package and shall be located at any one of the toll plazas or administrative building and shall have monitoring equipment, online information acquisition equipment, processing equipment etc. It shall also have a graphic display board showing the highway and the locations of equipment and of incidents ....

1.3 **Emergency Call System**

Purpose and General Information

This is a communication medium to be installed on the tunnel and to be used by the users to make alarm call to the CCR in case of accidents & other problems in the tunnel.

**Location**

ECB shall be installed every 2km on either side of the road with one unit directly across the road from the other i.e. two call boxes every *2*km. It shall be placed along the left side of the carriageway for each direction of travel on the verge adjacent to the hard shoulders. At each location one ECB shall be master and the other slave. The master ECB shall be equipped with fibre optic interface, solar panel, battery. back-up and voice communication mechanism and shall also comply with all the requirements specified in this section for ECBS. The slave ECB shall be equipped at least with - activation button, vandal sensing mechanism, call progress indication LED, microphone, speakers - in a weatherproof housing. To discourage motorists who break down near the start or finish of the Tunnel from leaving it to obtain assistance, no telephones should be provided within the first and the last 300meters.

To achieve maximum visibility, care should be taken to avoid sitting on telephones near structures (e.g. bridge piers), particularly where these are close to the hard shoulder on the left-and bends.

Based on the above policy and the site condition, the location of the ECBs can be adjusted within 10% variation, however, only with the consent of the AUTHORITY. The optical fiber and splicing boxes shall be placed in the central median.

**Major Components**

Main components of the Emergency Call subsystem are:

1. Field components:

a. Emergency Call Box - Master and Slave. units

b. (Solar) power supply

c. Guard rail for protection

2. CCR components

a. ECB server

b. Headphone, speaker and microphone (Answering Unit)

c. Voice recorder/logger

d. Application software

e. Database software

**Functional Specifications**

1. The system shall be connected to the CCR over the OFC backbone.

2. ECB shall have a loudspeaker, microphone, solar panel,and battery and activation button with

LED indicating conversation. It shall be housed in vandal proof casing and operated in Tunnel

noise levels with built in diagnostic features.

3. The road user just needs to press the push button on the ECB and shall be connected to the CCR. In case the CCR operator is busy, the user shall hear a recorded message and shall hold till he/she is connected. The Master unit shall be connected to the CCR over the communication backbone. The Slave unit shall be connected to the CCR through the Master unit.

4. The CCR can also call any specific ECB for testing/calling in which case the ECB shall ring. The ring shall go off when someone presses the push button and connects to the CCR.

5. The ECB shall have the following features:

a. Vandal proof casing with tamper detection switch

b. Push button

c. Activation LED

d. Loudspeaker

e. Microphone

f. Two-way communication between ECB and CCR s. Solar panel with batteries

6. ECB shall have hands free operation.

7. Each ECB shall have use. instructions in Hindi, English, Marathi and Guajarati pasted or printed on it along with graphical instructions.

8. Reflective stickers facing the motorist shall be pasted on the ECB indicating that it is a phone.

9. The CCR software shall manage the calls to and from the ECB.

10. The ECB shall have a Ringing Tone to indicate progress of call when button is pressed; the Confidence Tone to indicate call is still connected when on hold and recorded message if line is busy.

11. There shall be up to four programmable auto dial numbers associated with the push button. The ECB shall automatically dial subsequent numbers if the first number is busy or unavailable.

12. The ECB shall automatically make an en9 call when the CCR telephone is disconnected.

13. All calls shall be recorded in the CCR voice logger/recorder along with date/time stamp. The voice recorder shall check for the following minimum fault conditions:

· Failure of recording electronics

· Failure of storage media used for recording

· Excessive recoverable errors on the storage medium

· Lack of activity on a channel

· Constant activity on a channel

· Constant ringing on channel (answered calls)

14. ECBs shall be programmable from the CCR and from the field by laptop.

15. The system shall have in-built diagnostics and shall be able to detect activation of tamper switch, mic/loudspeaker faulty, line faulty, low DC voltage online, cross talk and short circuit. Any diagnosed problem shall trigger an audio video alarm in the ECB server at CCR.

16. The diagnosed problems shall be stored in the system as events in the CCR. It should be possible to draw and print report of all such events on time and event category basis. ECB software at CCR shall allow recording and storing of maintenance and corrective action of each event when it is resolved.

17. ECB shall be powered by DC batteries which in turn shall be charged by solar panel. The battery shall support 7 days of operation (under normal circumstances) with minimum talk time of 90 minutes over 3 days in succession in case there is no sunlight for this period.

18. The ECB shall have tamper resistant screw bits on the outside and shall be security locked. It shall not be possible to open the ECB with normal tools or keys.

19. ECB foundation shall be concrete. Cables (communication/power) shall enter from the base of the ECB foundation.

20. Each ECB pillar shall be numbered.

21. The ECB mic/speaker shall be located 1-1.5m above ground.

22. The system shall not permit cancellation of any call before answering.

23. CCR Equipment

a. The CCR equipment shall consist of an ECB server with a large TFT display screen and voice logger for recording of all calls. It shall be possible to play back any call by the time specified. Playback should not interfere with record function. The screen shall show the map of the Tunnel with all Emergency telephones marked in accordance with their actual locations.

b. The GUI should be user friendly. ECBs shall be displayed in grey colour icons on the screen. When a call is initiated, the icon shall turn green and blink. When the call is in progress, the icon shall be green and stationary. On-hold calls shall be displayed in orange blinking. Faulty ECBs

shall be displayed in red, without blink.

c. The software shall have i.e., following features:

i. password protected & accessible only with relevant passwords

ii. data logging with the currently logged user/ operator details

iii. different levels of authorization for logging into the system

*iv.* automatic Call location identification

*v.* call disconnection by operator only

*vi.* operator call back facility

*vii.* automatic testing facility running in the background at operator selectable intervals *viii.* operator initiated ECB test facility

ix. facility for holding at least 10 calls from ECB's

x. Low battery and tamper alerts.

d. The following shall be recorded by the system software:

i. Time of incoming call

ii. Time of call answering

iii. Time of call termination

*iv.* Time of fault occurrence

*v.* Time of happening of events

e. It shall be possible to:

i. connect to any of the Calls on Hold

ii. hang up the· call

iii. put on Hold the currently connected call

*iv.* Call back any of the ECB
monitor faults and events
vi. Send e-mail to defined personnel intimating them about emergencies.

f. It shall be possible to draw the following l"(minimum reports for each ECB as well as all/selected ECBs:

i. Call count based on time period selection

ii. Average call duration

iii. Average waiting period for on-hold calls

iv. Unanswered calls (count)

*v.* Fault and diagnostics report

*vi.* Incident category-wise report

vii. The reports shall be tabular as well as graphical.

24. The following technical specifications are advised for ECBs. However the system integrator/operator can choose any other technology as long as other requirements are met.

a) Working : Work on VoiP

b) Communication: Ethernet type *over* optic fiber

c) Power: 12/24V DC, solar powered max 10W

d) Audio output : >95dB

e) Microphone : unidirectional, noise cancellation type

f) Wind speed resistance : 180kmph.

g) Mean Opinion Score : Min 4.0

25. ECB shall connect to the Outdoor Technical Cabinet Switch on optic fiber port/copper port

(Ethernet may also be used, wherever feasible).

26. The ECB shall be vandal resistant in construction. It shall be made of stainless steel/

Aluminum alloy/ FRP.

27. ECB components shall be corrosion resistant; PCBs shall be coated to prevent water,

moisture and fungus.

28. Each ECB shall be protected against external EMI, lighting and static by adequate shielding

and earthing. The enclosure shall be provided with a grounding lug for connection to ground wire.

29. ECB enclosure shall be IP65 rated and shall be vermin and rodent proof. Doors shall be with

labyrinthine seal, butyl-rubber gaskets, security locks, and metal hinges in conformity with

UNE20324 standard.

30. The ECB shall operate in full duplex mode and use signaling which is inaudible to the user.

31. It shall be possible to adjust the acoustic properties.

**1.4 Variable Message Signs (VMS)**

Purpose and General Information Va riable Massage Signs (VMSs) are · to be installed for

conveying the traffic conditions ahead to the drivers on rea l time basis as well as to display

messages to support nationa l road safety campaigns. It may also include the variable traffic speed limit depending upon the requirements. Variable message signs (VMSs) shall provide traveler information for warning, regulating, routing, and managing the traffic in order to improve the overall traffic flow. The philosophy is to inform the driver of impending conditions-with up-todate information. The overall goal of VMS application is to provide permanently located signs that can be programmed remotely to communicate with the drivers the necessary information such that the driver can choose or be directed to the most appropriate route. The VMSs shall be controlled from the main CCR. Based on req uirement, the VMS may be fixed or portable in natu re. VMSs shall be used during the following cooditions:

Recurring Conditions

Mainly peak-period traffic congestion where demand exceeds capacity for relatively short periods of time.

· Non-recurring Conditions

Caused by random or unpredictable incidents. An "incident" is defined as any non-recurring event that causes a reduction of roadway capacity or an abnormal increase in demand. Such events include traffic crashes, disabled vehicles, spilled cargo, Tunnel maintenance and construction projects and adverse weather conditions.

***VMS Usage Priorities***

VMS should be used whenever pertinent messages wi ll assist motorists to make helpful decisions. If, however, a situation arises, which requires the usage of a specific VMS for more than one ongoing condition, the following priority criteria should be used for displaying messages, in the order listed.

**Safety**

Any VMS message that is necessary to provide safety to the motoring public has the highest priority. Examples include failure of an Tunnel bridge, roadway or any major incident. In general, safety messages should be kept current and relate to a specific safety campaign. The period of time that a specific message is displayed for a safety campaign should be limited to a few weeks. Motorists tend to ignore messages that are displayed for long periods of time.

· **Roadway Closure**

The VMS message shall include motorists regarding the roadway (particular carriageway, lanes of the Tunnel or crossroad) closure is important because such a closure directly affects the route a driver would take.

· **Minor Traffic Impact**

A pre-warning message shall generally be used for planned full closures of carriageway of particular part of the Tunnel. The message shall be displayed no more than four days prior to the closure, and shall be immediately replaced with an appropriate message when the closure commences.

· **Pre-Warning**

This category includes construction lane closures, blocking-incidents, and delay information.

·**Test**

Test messages may be used to sign operation for testing the operating system and prior to placing a VMS into service.

**Public Service Information**

Public service information messages do not require the drivers to make any unexpected maneuvers with regard to upcoming traffic conditions. Some examples include "Buckle Up,"

"Speed Kills," and '~Don 't Drink and Drive."

Various situations where VMS would be appropriate are as below:

· Incident signs as accidents, traffic diversions, incident management, monitor road work (men at work) adverse weather and. road conditions and operation with lane control signals; .

· Traveler information such as display of road construction activity in near future, messages for testing of the system and special events that effect the traffic flow;

· Public service announcements like messages related to driver safety campaign.

**Location**

VMS shall be provided as per locations determined later. A general policy adopted for locating VMSs is to provide VMS at an average interval of 1 Okm in each direction (not necessarily on the same gantry) to guide and forewarn the users about the traffic and weather conditions on the Tunnel. The most critical locations for insta lling permanent VMSs ·.are in advance of interchanges or Tunnels where drivers can have the opportunity to take some action in response to messages displayed on VMSs. A VMS should not compete with existing roadway signs.

Drivers generally do" not anticipate using a different route until they see and read a VMS message. Drivers who are traveling in the inside lanes need ample time to read the message and change lanes to exit.

In general, a VMS should be permanently installed at the following locations:

4) The minimum distance of VMS on an Tunnel should be 1.5 km. prior to decision point. The signs should be visible from a distance of 300m.

5) There should be clear distance between existing road sign and VMS. The minimum distance between road signs and VMS should be at least 250m.

6) The average driver of motorized vehicle at high rate of speed can comprehend two messages panels. Each parcel should .be complete phrase and each phrase should be independent of the other. The messages shou ld consist of:

A problem statement Road work/accident ahead

An effect statement Delay/congestion

An attention statement for certain group Motorist

An action statement Take the next carriageway

7) Software - The VMS application software shall be installed in the CCR and shall have the following features:

· GUI display

· Login/password protected access

· Database for storing messages and history

· Reports for- preconfigured messages, login time and user, date/time of display, fault history.

8) Maintenance walkway shall be. provided on the gantry at the rear of the signs . All component parts shall be easily and readily accessible by a single person for inspection and maintenance. There shall be room for a technician to work. The VMS should have in-built lighting to assist maintenance work during night.

9) Standards

VMS shall be designed to comply with the following protocols:

· Et';J 12966 parts 1 ,2 and 3

1 0) VMS shall be full matrix, true colour. It shall be made of modules and shall have equally spaced LEOs.

11) Text disp.lay- VMS shall be compliant to EN 12966. This includes. the following for LED panel:

· Beam : 83

· Colour : C1

· Luminance : L3

· Temperature : T3

· Resistance to pollution : 03

· For wind pressure on enclosure refer EN 12899

13) The LED Cluster shall consist of individual LED's encapsulated in a resonated plastic housing proving protection to the elements under worst climatic conditions. . .

14) The modules shall be individually addressable and field re placeable.

15) Failure of one LED module should not affect the output of any other.

16) The system ~esign shall be so as the display is legible from a distance of between 15m to 300 m in all weather and lighting conditions.

17} Elaborate Fault diagnostics shall be provided as per EN12966 or other equivalent international standards. Each pixel shall be monitored, and feedback shall be provided for the healthy status. Minimum of the following shall be provided:

· Power Failure at VMS.

· Processor PCB Failure

· LED Cluster Failure

· Loss of incoming message *I* data not properly received.

· Temperature monitoring

18) The VMS shall withstand shock and vibration existing on the Tunnel.

19) Controller functionalities

· The controller unit shall provide brightness control facility. The intensity of the VMS shall have at at least six levels and it shall select the correct level automatically depending on ambient light conditions. For this, ·the VMS shall have photo sensor and dimmer control. ·-

. The controller unit shall provide monitoring of ambient temperature of the housing.

· The controller shall be provided with a test port for local diagnostics via laptop.

20) The VMS software should permit the following:

· Broadcast messages

· Specific address messages

21) It shall be possible to perform fault diagnostics from the central control room via the software.

22) Maintenance panels shall be provided on the rear of the housing

23) Maintenance walkway shall be provided on the gantry at the rear of the sign-case. All component parts shall be easily and readily accessible by a single person for inspection and Maintenance. There

shall be room for a technician to work. Access shall be made by entering the side of the housing. The housing shall be weather tight, and compliant to the NEMA 3R Standard. The bottom panel of the housing shall have a minimum of four drain holes, with snap-in, drain filter plug inserts.

24) Ventilation - The ventilation system shall be forced into air. The system shall be designed to adequately cool the pixels from all sides along with the front and rear of the display module and all other internal components. The ventilation system shall have the following properties:

Positive pressure (exhaust fans are not acceptable).

· The fans shall have ball or roller bearings, shall be permanently lubricated and shall require no periodic maintenance. The fans are to be positioned in· such a manner so as to provide a balanced air flow to the ventilation system in the event of failure of any fan.

**a) Sign-case**

· All parts shall be made of corrosion resistant materials, such as plastic, stainless steel or alum inum. Painted steel is not acceptable. No se lf-tapping screws shall be used. The finish shall be matte black. The main body of the sign housing shall be constructed of aluminum with a natural mill finish. All exterior seams shall be continuously welded by an inert gas process, except for the coated fascia material. Tfie sig n-case shall be constructed of non-ferrous material to avoid rusting. The VMS sign-case shall have CFL lighting for maintenance during low light conditions.

· The performance of the sign, including the visibility and leg ibi lity of the display, shall not be impaired due to continuous vibration caused by wind, traffic or other factors.

· The angular alignment of the sign housing shall be adjustable in the vertical direction from (0 to 10 degrees) down in one-degree increments to optimize the viewing angle.

· The housing shall be capable of withstanding the following conditions for the Vibration Test

1. Frequency range : 10- 50Hz
2. Vibration amplitude : 0.35mm·
3. Duration of endurance : 20 sweeps cycle
4. Duration at resonant frequency : 30 min+ 1 min

The Gantries for the VMS shall be designed, and the design shall be got approved from the AUTHORITY. It includes all civil work like foundations etc. and shall be done as per relevant standards.

**1.5 Automatic Traffic Counter-cum-Classifier (ATCC)**

Purpose and General Information

· This system shall be used for identifying and recording all types of vehicles on the Tunnel for effective··monitoring and data collection at the Control Centre. The· system shall be capable of detecting and recording all types of vehicles plying on the Tunnel.

· Besides the above vehicle classes, the system shall be capable of classifying any other vehicle category as per need. Vehicle classification should be user selectable based on vehicle parameters.

· The system shall)1ave interface with the ATMS software for central monitoring.

**Location**

· ATCC is proposed -to be installed at at suitable location. The final location may be adjusted as

per the site condition, only with the consent of the AUTHORITY/Traffic and Transportation expert.

· The ATCC cabinet shall be installed in median or on the side of the Tunnel at a distance of

2 to 3 meters from the soft shoulder.

**Major Components**

Main components are:

a) Field components- consists of:

a. ATCC roadside cabinet *I* electronics/data logger

b. In-road/non-intrusive sensors and cables

c. Field computer/laptop

d. Power supply

e. Lightning protection and earthing

a. ATCC server

b. Application software

c. Database software

d. Report printer

**Specifications**

*Volume-Ill: Schedules*

· The ATCC should be designed for 8 lanes of traffic i.e. one cabinet/data logging unit should be

able to record data for at least 8 lanes (4 in each direction)

· System shall use a combination of loop and piezo sensors or any other sensor mechanism

(intrusive or non-intrusive) for correctly counting and classifying

vehicles.

· Piezo sensor installation shall be in concrete. ASTM 1318-02 recommends a concrete pavement

of 90m (60m before sensor and 30m after) to ensure good accuracy.

· The A TCC shall detect all classes of vehicles as per toll classification scheme.

· One or more of the following information shall be generated by the ATCC for each lane to

correctly count and classify the vehicle:

a. Vehicle length ·

b. Vehicle speed

c. Number of axles

d. Axle spacing

e. Axle load (WIM) and GVW

f. Vehicle profile

g. Vehicle image

h. Any other proven technology with the consent of the Engineer and AUTHORITY

2. The ATCC shall provide the following additional information:

a. Occupancy

b. Headway

c. GaiJ

d. *Average* Speed

e. Flow rate

c) Data logger (roadside electronics): Th~ requisite number of entry and exit ports to communication systems shall be provided. The logic unit shall be micro-processor based. The systems be able to count and classify vehicles in each lane. There shall be an indication to display vehicle detection.

d) Data logger shall have a Tamper Detection Alarm facility. Any effort to tamper with th~ data logger shall trigger an audio and visual alarm in the CCR.

e) Data collection: The system shall be capable of sending data to the ATMS Software which shall enable the Software to count and classify the vehicles, and provide other required information Data collection shall be by RS232, RS4~2 or RS485 interface or IP connection.

f) Data Storage: The system should be able to upload data to the system as it occurs. The unit shall store data of at least two weeks in event of communication failure.

g) System Accuracy (95% confidence), whichever is applicable

a. Vehicle length(m): + 5%

b. Vehicle speed (kmph): + 1.5%

c. Vehicle count(nos.): + 1%,

d. Number of axles (nos.): +2%

: +2%,

h) Coincidence detection (lane straddling): The ATCC shall be capable of determining and recording vehicles that straddle adjacent lanes. This reduces double counting of vehicles on sites Where lane discipline is a problem.

·i) Weather: The ATCC shall be capable of working with above mentioned accuracies, 24x7, in all weather conditions including heavy rain, dense fog and specified temperature range.

j) Reverse detection: The ATCC shall be capable of detecting and recording any vehicles traveling in reverse direction.

k) Data retrieval: The system shall be capable of data retrieval, direct data transfer through the Fiber Optic Network or locally through laptop.

I) Recording capability: The system shall have capability of recording vehicle counting and classification, speed, headway at set interval of 1-10 minutes.

m) Compatibility: The system shall have compatibility to transmit data over Optical Fiber Cable.

n) Fault monitoring: The system shall be capable of detecting and reporting the f0llowing fault -- events:

· Mains power failure

· Battery low voltage

· Modem communication error

· Laptop communication error

· CPU reset

· CPU failure

· Sensor fault (for each sensor)

· Door tamper

**Software**

The Application Software shall have the following features:

· It shall be GUI based

· The Opening Screen shall have password authentication

· Communications Parameters setting

· Configuration Parameters setting

· Raw and Binned data Retrieval

· Vehicle by vehicle Real Time Traffic Display

· Diagnostic Functions - Sensor Test

· Vehicle Classification Configuration & Weight Limits

**Excavation and Earth Works**

Excavation shall include careful removal of all materials or whatever nature and whether dry or wet, necessary for the construction of work, exactly in accordance with lines, levels, grades and curves shown on the plans

The bottom of the foundation shall be levelled both longitudinally and transversally or stepped as directed. Should any of the excavation be carried down to a level below the specified level.

The excavation shall be carried out in accordance with the dimensions shown in the sanctioned drawings.

Any obstacle encountered during excavation shall be reported immediately to the Engineer-in-charge and shall be dealt with as instructed by him. Removal of buried piping or cables shall not be done without prior permission of the Engineer-in-charge and the contractor shall take all measures to protect such lines. Cost of such protective measures and deemed to be included in the rates for various items of excavation. No blasting shall be permitted for excavation of foundation even in rocky formation without the prior permission of the Engineer-in-charge

The contractor shall provide suitable drainage arrangements, to prevent surface water from any source entering the foundation pits, at his own cost.

The contractor shall not undertake any concreting in foundation until the excavation pits is approved by the Engineer-in-charge.

If the soil is soft, loose or slushy the trench shall be widened for allowing berms on either sides or the sides sloped or shored up. During excavation if rocks or rocky soils are found, (if approved as suitable for foundation), those shall be leveled as far as possible and the small spaces which are difficult to level shall be filled in with Controlled Low Strength Material (CLSM).

Backfill Material.

Foundation trenches, column bases and the like shall be backfilled with selected excavated materials as described for imported fill, if approved by the Engineer.

Filling shall be done after the concrete or masonry in the foundation has fully set and its curing completed. It shall be done in such a manner as not to cause undue thrust on any part of the structure.

Back filling around completed foundations shall be done to the lines and levels shown on the drawings, including any trimming of the surfaces, as may be necessary. This will be done with selected and approved earth from excavation or otherwise with borrowed materials as directed by the Engineer-in-charge. Where sufficient suitable material is not available from the excavation, The Engineer-in-charge may direct to import suitable earth from different sources. The refilling shall be done in horizontal layers of thickness not exceeding 15cms from pocket with careful watering, ramming and rolling etc., to obtain necessary level of compaction.

Imported Fill

Imported fill shall be selected, graded, hard, granular fill, free from clay and deleterious matter, with 100% free of stones larger than 75mm, upto 50% passing a 5mm mesh sieve and not more than 20% passing a 75micron sieve. It shall contain less than 0.2% total sulphates and less than 1.0gm per liter of water-soluble sulphates in a 2:1 water soil extract. Total soluble salts shall not exceed 2%

Anti Termite Treatment

Area should be cleaned before application and the treatment should be done as per the contractual specifications/ IS code. Saturation of the soil with the chemical emulsion to be ensured.

Treatment along outside of foundations: The soil in contact with the external wall of the building shall be treated with chemical emulsion at the rate of 7.5 l/m2 of vertical surface of the sub-structure to a depth of 300 mm. To facilitate this treatment, a shallow channel shall be excavated along and close to the wall face. The chemical emulsion shall be directed towards the wall at 1.75 l/m of the channel. Roding with 12 mm diameter mild steel rods at 150 mm apart shall be done in the channel. If necessary, for uniform dispersal of the chemical to 300 mm depth from the ground level. The balance chemical of 0.5 l/m shall then be used to treat the backfill earth as it is returned to the channel directing the spray towards the wall surface.

**RCC/PCC works**

Cement

The cement material used shall comply with relevant codes as specified in IS 456-2000. Bags of cement shall be stored in a waterproof store with a raised floor. The cement shall be used in the order in which it arrives at site.

Additives shall not be permitted without the consent of the Engineer. Samples of cement to be used in the works shall be approved by the engineer and samples shall be provided for approval before delivery of materials to site.

Aggregate

Aggregates used in the construction shall comply with the requirements of IS 383:2016, "Coarse and Fine Aggregates for Concrete – Specification

Coarse Aggregate

As far as possible, preference shall be given to natural aggregates, such as crushed stone, gravel, and sand, which meet the requirements of IS 383.

Recycled aggregates shall be used in accordance with the guidelines and norms specified by:

- Green Rating for Integrated Habitat Assessment (GRIHA)
- Indian Green Building Council (IGBC)

The use of recycled aggregates shall be subject to the approval of the Engineer and shall meet the requirements of IS 383. The nominal size of the graded aggregate shall be 20 mm to 5 mm or as specified.

Fine Aggregate

As far as possible, preference shall be given to natural fine aggregates, such as river sand, quarry dust, or other naturally occurring materials that meet the requirements of IS 383.

Aggregates shall be stored on clean, self-drained concreted or paved areas with adequate division walls to prevent contact between different grades or types of aggregate. Graded aggregates, which have segregated in stockpiles, must be thoroughly mixed before use.

Water

Water used for mixing and curing shall be clean and free from injurious amounts of oils. acids, alkalis, salts, sugar, organic materials or other substances that may be deleterious to concrete or steel. Potable water/RO water is generally considered satisfactory for mixing and curing concrete

Admixtures

Admixture. if used shall comply with the requirements of IS 9103:1999, "Specifications for Concrete Admixtures

The workability, compressive strength and the slump loss of concrete with and without the use of admixtures shall be established during the trial mixes before use of admixtures

Approval: The use of admixtures shall be subject to the approval of the Engineer, based on the results of the trial mixes.

Quality Requirements: Admixtures shall meet the following quality requirements:

- Chemical Composition: The chemical composition of the admixture shall be as specified in IS 9103.
- Physical Properties: The physical properties of the admixture, such as density and viscosity, shall be as specified in IS 9103.

Reinforcement

The reinforcement shall be of Mild steel and medium steel wire, conforming to I.S. 432-1960 or TMT bars conforming to I.S. 1786-2008 or deformed steel bars conforming to I.S.1139 with up-to-date modification.

Epoxy coated reinforcement where specified shall be fusion bonded conforming to ASTM A775.

Bars shall be bent cold by machine or other approved means. Reinforcement shall be accurately positioned and rigidly supported and tied with binding wire to prevent displacement during the concreting.

Bar bending schedules shall be prepared by the Contractor in accordance with the drawings and BS 4466 at least fourteen days in advance of any bending of reinforcement, and they shall be approved by the Engineer before any bars are cut or bent. Bars once bent shall not be straightened or rebent. Heating or welding of the reinforcement will not permitted unless the prior consent of the Engineer has been obtained in writing.

Reinforcement shall not be stored in contact with the ground.

Mixes and Mixing of Concrete

Unless otherwise specified concrete in various locations shall be as follows:

| **Usage** | **Concrete Class** | **Min. Cement Content** | **Max. W/C Ratio** |
|---|---|---|---|
| Reinforced cement concrete in all locations | 20N/mm2 | 330 | 0.5 |
| Plain cement concrete in floors and pacing and other situations not covered under above | 20N/mm2 | 330 | 0.5 |
| Binding Concrete | 1:3:6 | 220 | 0.55 |
| Plain cement concrete 1:2:4 for underground piping benching and similar | 1:2:4 | 330 | 0.55 |

Where the concrete is specified to give strength more than mentioned above, the concrete shall be designed and tested according to IS 516 or to other approved standard to the full satisfaction of the Engineer.

The slump test shall be used as a guide to the workability of the mixed concrete, which shall be carried out by using a slump cone in accordance with IS 1199: 1959 "Methods of Sampling and Testing of Concrete"

The Engineer’s approval to the Contractor’s proposals for concrete proportions in no way relieves the Contractor of his responsibility for providing concrete of the minimum strength required.

Concrete shall be mixed in an approved Ready Mix Concreting (RMC) Batching Plant. The Volume of Mix shall be as per approved Mis Design Report.

The provisions of IS 4926 will govern the supply and use of ready mixed concrete.

Sampling and Strength of Designed Concrete Mix

Samples from fresh concrete shall be taken as per IS 1199 and cubes shall be made, cured and tested at 28 days in accordance with IS 516

Adequate number of cube moulds along with slump cone shall be placed at work site. The samples shall be taken in accordance with relevant BIS/ technical specifications. As per clause 15.2.2 of IS:456, the frequency of sampling shall be as follows:

| **Quantity of Concrete (cum)** | **No. of samples** |
|---|---|
| 1-5 | 1 |
| 6-15 | 2 |
| 16-30 | 3 |
| 31-50 | 4 |
| 50 & above | 4+1 additional sample for each additional 50 cum or part thereof |

Freshly laid concrete shall be protected from rain. After about two hours of laying, when concrete has begun, to harden, it shall be kept damp by covering with wet gunny bags for 24 hours and7 days continuously. If specified curing may be done by covering concrete with special type of waterproof paper so as to prevent water escaping or evaporating.

SLUMP TEST

The Contractor shall keep at the site of the works for the constant use of the Consultant's representative a standard slump test mold and shall provide facilities throughout the construction for tests to be made as and when the Client may require. The slump cannot be definitely stated until tests have been made using the materials adopted for the work, but it is anticipated, that the slump of between 25mm to 50mm will be required.

The Contractor at his own expense shall establish a field laboratory to carry out all preliminary tests, work tests and also to work out grading and proportioning of aggregates in order to obtain and maintain uniform quality of work. A 150 mm cube testing machine shall be installed by the contractor at his own expense to ascertain the strength of concrete from time to time. The contractor shall supply all materials, labour and testing machines for preparing and testing sample as required by the Engineer. The concrete shall also be got tested in an independent laboratory approved by the Engineer at the discretion of the Engineer or his authorized representative at no extra cost.

TRANSPORTING PLACING AND COMPACTION OF CONCRETE

The concrete shall be transported maintaining required workability in a manner such as to avoid the segregation of the constituent materials, and loss of any of the ingredients. It shall be deposited as nearly as practicable in its final position to avoid re-handling. It shall be placed and compacted before setting commences and should not be subsequently disturbed. Methods of pouring should be such as to preclude segregation, and to avoid displacement of reinforcement and movement of formwork.

The concrete should be thoroughly compacted and fully worked around the reinforcement, around embedded fixtures and into the corner of the formwork without formation of honey combing, pinholes or surface irregularities and any other defects whatsoever. The use of mechanical vibrators having capacity of producing vibrations at a rate not less than 5000 cycles per minute is recommended. Over vibration or vibration of very wet concrete is harmful and should be avoided; under vibration is also harmful. In addition to mechanical vibration, sufficient hand tools must be used to ensure full consolidation around reinforcement and at edges and corners.

The deposition of concrete shall be carried out as continuously as possible to reduce to a minimum joint between new concrete which has set. Where construction joints are necessary, they shall be formed at right angles to the axis of the member concerned by the insertion of rigid stopping off form, against which concrete can be properly rammed. Concrete shall not be dropped from a height of more than 1.0 M. No unset concrete shall be brought into contact with unset concrete containing cement of different type. Special permission and instructions shall be obtained when concrete has to be deposited under water. Under water concreting shall be done with the help of tremi pipe line only. Concrete shall contain 10% more cement than that required for the specific mix placed in dry condition.

Accumulation of set concrete on the reinforcement shall be avoided. Before fresh concrete is deposited upon or against any concrete which has already hardened, the surface of hardened concrete shall be well roughened, if necessary, by chipping and all Latinate removed. The surface shall then be swept clean with wire brushes, thoroughly wetted and covered with a thin layer of cement mortar.

Care should be taken such that there are no cold joints while laying concrete.

Use of Vibrators:

a. Immersion vibrator shall be inserted vertically at points not more that 450mm apart and withdrawn when air bubble seizes to come to the surface. Immersion vibrator shall be withdrawn slowly.

b. The immersion vibrator shall penetrate the layer being placed and also penetrate the layer below while the under layer is still plastic to ensure good bond and homogeneity between the two layers and prevent the formation of cold joints.

c. The use of surface vibrators will not be permitted under normal conditions. However, for thin slabs, such as highways, runways and similar constructions, surface vibration by specially designed vibrators may be permitted upon approval of engineer.

**Shuttering/ Formwork for Concreting**

Formwork, centering, and shuttering should be constructed with materials that effectively prevent grout leakage and absorption of water from the concrete. It is recommended to use mild steel (MS) sheets as required, adhering fully to the standard specifications outlined in IS 1200 Part V. These measures shall be undertaken prior to laying the concrete to ensure confinement, support, and the maintenance of the concrete's position.

The design of formwork shall be per IS 14687:1999 "Formwork for Concrete - Code of Practice"

The following upward cambers are suggested to the formwork

i. Cantilevered slabs - 3 mm to every 1.5m of span

ii. Cantilevered beams - 6 mm to every 1.5m of span

iii. Slabs over 3m span - 3 mm to every 3.0m of span

iv) Beams over 6m span - 6 mm to every 3.0m of span but not exceeding 40mm.

Removal of formwork

The removal of formwork is governed by IS 456:2000, which specifies the guidelines for the removal of formwork for different types of concrete elements

The formwork shall be removed avoiding shock or vibration that may cause any damage to concrete.

Formwork shall be removed only when concrete reaches the strength to withstand various loads while striking as per above IS codes.

| **Type of Formwork** | **Stripping time** |
|---|---|
| Vertical formwork to walls, columns, beams | 16-24 hours |
| Soffit formwork to slab (props to be re-fixed immediately after removal of forms | 3 days |
| Soffit formwork to beams (props to be re-fixed immediately after removal of forms) | 7 days |

**Expansion Joints**

Expansion joints to be provided as per guidelines and according to IS 3414. Unless otherwise specified, the expansion joint filler shall be a 20mm thick bituminous board, subject to approval.

Sealant : The expansion joint shall be pointed with a 2-part polysulphide sealant, conforming relevant IS , to a minimum depth of 20mm.

**Wall Ties**

Unless otherwise specified wall ties shall be zinc coated, 3mm mild steel fish tail type, 300mm long to comply with the requirements of IS 4326:.

**Vapour Barrier**

Vapour barriers shall be polythene and shall consist of 1000 micron approved hydro-carbon thermoplastic resin or equivalent obtained from an approved manufacturer.

**Internal Civil Finishing Works**

Brickwork

The following I.S. apply to this section:

| I.S. NO. | SUBJECT |
|---|---|
| 1077-1992 (R2002) | Common burnt clay building bricks |
| IS: 1200 (Part-III) – 1976 | Methods of measurement of Brick works |
| IS: 2212 – 1991 | Code of practice for brick work |
| IS: 3495 (Part I to IV) 1992 (R2002) | Methods of tests on burnt clay building bricks |

Classification of bricks and dimensions

Bricks shall be classified on the basis of their minimum compressive strength as given below :

| Class Designation | Average compressive strength | |
|---|---|---|
| | Not less than (N/mm2) | Less than (N/mm2) |
| **12.5** | 12.5 | 15 |
| **10** | 10 | 12.5 |
| **7.5** | 7.5 | 10 |
| **5** | 5 | 7.5 |
| **3.5** | 3.5 | 5 |

The brick may be modular or non-modular.

| Type of Bricks | Nominal Size mm | Actual Size mm |
|---|---|---|
| **Modular** | 200 x 100 x100 | 190 x 90 x90 |
| **Non Modular** | 230 x 115 x75 | 225 x 110 x 70 |

The selection of bricks shall be done as per the requirement and specifications of the work. The quality of clay bricks, Fly ash bricks & Solid concrete blocks & other masonry units shall be as per relevant IS standards bricks shall be soaked well in water for at least 1 hour prior to use and will be in surface dry condition at the time of lying.

Cement mortar as specified, shall be made with fine natural sand and specified Portland cement.

Block Masonry

Precast concrete blocks shall comply with the requirements of IS 2185 (Part 1 to Part 3):2005. The materials used for the manufacture of blocks (i.e. cement, aggregates and water) shall comply with the relevant clauses as specified in "Concrete Masonry Units - Specification".

Precast concrete blocks shall be made in approved block making machines in the thickness required. The materials for all blocks shall be mixed upon a clean mixing platform or in an approved mechanical mixer and shall be gauged with sufficient water to enable the materials to bind together under pressure and thereafter placed in the block making machine in layers not exceeding 75mm, each layer being thoroughly tamped or, if approved, machine vibrated.

Types of blocks to be used are as follows:

Minimum Compressive Strength – as per IS: 2185 (Part I & II)

Size of Block(mm)

Length : 400, 500 or 600 mm

Height : 200 or 100 mm

Width : 50,75, 100, 150,200, 2500r300 mm

- Non-Load Bearing Walls : Not less than 3.5 N/mm2
- Load Bearing Walls : Not less than 7.0 N/mm2

Blocks may solid or hollow for load bearing walls but they must be solid below plinth level.Blocks Made from natural and recycled materials like Cement, lime, sand, water, lime, Gypsum and an expansion agent like aluminum powder CAN BE USED in accordance with the guidelines and norms specified by:

- Green Rating for Integrated Habitat Assessment (GRIHA)
- Indian Green Building Council (IGBC)

Testing of Blocks

Testing of blocks shall be in accordance with IS: 2185: Part I

Mortar

Cement and water for mortar shall be as specified for “concrete work”

Sand for mortar to be natural sand, crushed stone, or crushed wadi gravel conforming to the requirements of IS 383:2016.

Plastering

The thickness of plastering shall be minimum 12 mm (1/2") with appropriate rendering as per IS 2402- 1963.

Flooring, Dadoing and Skirting Works

Flooring with ceramic and vitrified tiles

The tiles shall be of approved quality, shape, size, color and free from any deformities, and shall comply to IS 13630 (Part 1 to Part 4):2014

The tiles shall be tested for its mechanical properties such as strength and hardness prior to usage and stacked in an enclosed space properly as per manufacturer’s instructions.

**Granite/ marble works**

The tiles shall be of approved quality, shape, size, color and free from any deformities, and shall comply to IS 3316:1974

- The marble/granite stone should satisfy the following requirements:
- The stone should be hard, even, sound and durable.
- The slabs should be of uniform color, free from stains, cracks, decay and weathering.
- The slabs shall be sawn or cut in plane parallel to the natural bed of the slope.
- They shall be cut in perfect line; and right angles should be maintained.
- They shall be uniform in size and the edges shall be truly square.

**IPS Flooring**

The Concrete Flooring shall be carried out in accordance with IS 2571- 1970. The workmanship shall comply with IS

3025:1983

- The sub base shall be of sand, PCC
- If the base surface is Cement concrete shall be placed in position and beaten with trowel till the surface is found covered with cream of mortar.

**Vacuum Dewatered Concrete Flooring**

Concrete is poured in place and vibrated with a poker vibrator.

**Polished Slab Granite flooring**

Polished granite slab shall be machine cut. Machine cut slabs shall have fine tooled dressing on all sides to full depth. Slabs shall be washed clean before laying. The bedding mortar of the specified mix shall be spread under each slab, slab shall be then laid on top, pressed so that the hollows underneath get filled and surplus mortar works up through the joints. The slabs should be tapped with wooden mallet and brought to level and close to adjoining slabs with thickness of joints not exceeding 1.5 mm. After laying each slab surplus mortar on the surface of the slabs shall be cleaned off and joint finished flush. Subsequent slabs shall be laid in the same manner. The joint shall be left raked out uniformly to a depth not less than 10 mm, when the mortar is still green. The surface of the flooring laid, shall be true to levels as directed by the Engineer-in-Charge. Slabs, which are fixed in the floor and joints the wall not less than 12 mm under the plaster, and floor shall be finished neatly and without waviness.

The flooring shall be cured for Fourteen days. The finished floor shall not sound hollow when tapped with wooden mallet. Measurement shall be on Sq. mt. basis. The rate shall include cost of all materials, labour and shuttering involved in all the operations.

**Glazed Earthenware/Tiles/Ceramic Tile Flooring, Dado and Skirting**

Glazed earthenware tile shall conform to I.S. 777-1970, specification for glazed earthenware tiles. When fractured they shall appear fine grained in texture, dense and homogeneous. The tile shall be flat true to shape, sound and free from flaws and other manufacturing defects.

Facial dimensions: The length of all the four sides of tiles shall be measured to the nearest 0.1 mm. The average value shall not vary more than + or – 0.8 mm from the dimension of the nominal size. The variation of the individual dimension from the average value shall not exceed + or – 0.5 mm.

Tolerance on thickness + or – 0.5 mm.

Water absorption: The average water absorption of the tile when tested and evaluated shall exceed 18 percent.

Impact strength: Tiles when tested for impact strength shall not have a value less than 0.020 Kg fm/cm.

Bedding over which the glaze tiles shall be laid as indicated and shall not be less than 10 mm at any place. Mix of bedding layer should be as specified. Tiles shall be soaked in water before laying.

Base shall be cleaned and wetted. The bedding shall then be laid evenly over the surface, tamped and corrected to desired levels and allow to harden enough to offer a rigid cushion to tiles. Before laying the tiles, cement slurry of honey like consistency 3 Kg /Sq. mt. shall be applied over the bedding. At a time, area to accommodate about 20 tiles shall be applied with cement slurry. Tiles shall then the washed clean and fixed in the grout one after the other. Each tile being gently tapped in its position till it is properly bedded and in level and line with adjoining tiles. The joint shall be as thin as possible but not exceeding 1.5 mm wide.

In the case of skirting and dado, the wall surface shall be covered with about 10 mm thick plaster of cement and sand mortar 1:3 and allow to harden. The plaster shall be roughened with wire brushes or by scratching diagonal lines. The back of the tiles shall be buttered with cement paste and set on bedding mortar. The tiles shall be gently tapped in position one after the other. Top of skirting or dado shall be truly horizontal and the joints vertical or as per required pattern.

The joints shall be racked to a depth of 5 mm and all dust and loose mortar removed. Joints shall then be flush pointed in White cement or in coloured cement in the case of coloured tiles. The surface shall be cured for seven days and then wash clean.

Mode of Measurement: Payment will be on Sq. mt. basis. Rate shall include cost of all materials labour and shuttering involved in all the operations.

**Painting**

The following I.S. apply to this section;

| I.S. NO. | SUBJECT |
|---|---|
| 5410-1969 | Specification for cement paint,colour as required. |
| 2932-1974 | Enamel, synthetic, exterior, under coating and finishing (First Revision) |

CEMENT PAINT

Cement paint shall comply with I.S. 5410-1969, specification for cement paint, colour as required. The material shall be in powder form, free from lumps that are not friable and when mixed with required volume of water shall be suitable for use on porous surface of masonry, concrete and rough plaster work.

PAINTING WOOD WORK

Paint shall comply with IS 3915:1984.All wood work shall be dried free from dust, dirt or any extraneous materials. Flat portion shall be smoothened with abrasive paper used across the grain prior to painting. All loose knots removed, and holes filled.

PAINTING STEEL AND IRON WORK

- Paint shall comply with IS 1573:1993
- The surface shall be thoroughly cleaned of dirt, fluxing material, other foreign material .
- Temporary rust protective materials applied to steel sheets to protect during transport and storage shall be removed with suitable solvent as a preliminary to other preparatory treatment.
- Surfaces already pretreated or primed in a factory shall be carefully inspected and damage areas shall be thoroughly degreased and cleaned of all dust and touch up.
- Priming coat shall be applied by brush, working in the paint into the fine dents and ensuring a continuous film without runs and holds.
- After the primer coat is harden and dry, Deep dents and scratches, if any shall be filled with paste
- Under coating shall be applied by brush. The film shall be allowed to hard dry, wet rubbed and cut down to a smooth finish ensuring that at no place under coat is completely removed.
- Finishing coat shall be applied for brush. Special care shall be taken while painting over bolts, nuts, rivets and overlaps etc.
- The painted surfaces shall present a uniform appearance and from streaks, blisters etc.

**Flush Door Shutters**

Flush door shutters shall be solid core type with block board coat, as indicated, and shall conform to I.S. 2202 (Part I) – 1983, specification for wooden flush door shutters (solid core type) Part-I plywood face panels. Except with regard to the sizes of shutter which shall be as indicated. Flush door shutter shall be non-decorative (commercial) type. Flush door shutters internally lipped, internal lipping may be provided separately or as one piece with the frame. The width of frame including lipping shall not be less 50 mm. Where separate lipping is specially desired, it shall be as indicated. Internal lipping shall have total depth of not less than 25 mm, joints shall not be permitted in lipping.

In the case of doubled leaved shutters, rebating shall be splayed or square as directed. Where separate lipping is indicated the depth of lipping at the meeting of stiles shall not be less than 35 mm.

Flush door shall be free from twist, or warp in plane and all the four edges of the door shutters shall be square. Both the faces of the door shutter shall be sanded to a smooth even texture.

Tolerance on nominal thickness shall be + or – 1.2 mm. Thickness of shutter shall be uniform through the variation not exceeding + or – 0.8 mm when measured at any two points.

Fibre Glass Reinforced Plastic (F.R.P) Shutters

F.R.P shutters shall be manufactured conforming to the specification as per IS 14856 and nomenclature of item and direction of Engineer in charge.

Blocks of any seasoned hardwood of bulk density not less than 450 kg/3 at 12 percent moisture content or any other

material of sufficient thickness and length shall be provided inside the shutter at suitable place to hold fittings and fixtures such as aldrops, tower bolt, handle, sliding door bolt, mortice lock etc. blocks for hinges shall be provided at predetermined places in the shutter so as to fix hinges mortice locks, tower bolts, aldrops, door closures, etc. The finished surfaces shall be buffed and polished with wax.

**Stainless Steel Work**

The stainless steel railing pipes, hardware's & accessories of specified grade to be supplied and installed at site as per the above mentioned specifications as per BOQ, drawings and approved by the Engineer – in – charge.

The material properties of stainless steel pipes and accessories should be confirming to SS 304 grade.

The stainless steel pipes shall be procured from approved manufacture and of approved grade. The quality stainless steel sheet and pipe shall be approved by client / consultant before proceeding with execution any item of work.

The pipe used for handrail shall be of 16 gauge thick. The welded links are to be ground and organ buffed to get the original finish of the surface of the material welded. The joints or junctions where two pieces are joined / welded to be precisely cut and then welded.

**Structural Glazing**

Scope includes design and execution of the work of providing semi unitized structural glazing with all the accessories such as extruded aluminum frames, aluminium composite panels, glass wool insulation, anchor clips, fasteners, brackets, gaskets, sealants, spacers, baker rods and related works perimeter flashing, continuous gutter system at each floor of the glazing, performance test etc., complete.

IS 875 (Part 3) : Code of practice for Design loads for buildings and structures Part- 3 Wind loads

AS-1288 1984 : Glass in Building ASTMC 1036-85

BS 626 : Glazing

Glass Saint Gobain/ Pilkington/ Galverbel 6mm thick heat strengthened, hard coated (Bronze of tint) Reflective glass possessing the following parameters.

| SL.NO. | DESCRIPTION | DATA |
|---|---|---|
| 1 | • Light information<br>• Transmission<br>• Reflection Ext.<br>• Reflection Int. | •<br>• 27 %<br>• 17 %<br>• 23 % |
| 2 | UV | 6% |
| 3 | • Energy characteristics<br>• ER<br>• EA<br>• SF | •<br>• 10%<br>• 76%<br>• 0.24% |
| 4 | Shading co-efficient | 0.28 |
| 5 | U – Value | 2.76 |
| 6 | Relative heat gain | 216 watts/ M2 |

**Aluminum Composite Panels**

Shall be from Alucobond or Renobond and thickness shall be 4mm. The colour to match with the colour existing

Environments

- 1.Structure Silicone
- 2.Dow corning
- 3.DC 995 1 Part & DC 983 2 Parts
- 4.Aluminium Sections
- 5.Indal Co./ Jindal / Bhoruka
- 6.Conforming to IS 63400 t5 /16063. Alloy AIMg SI-05
- 7.Minimum thickness = 2mm
- 8.Anodization: Anodized to approved colour to minimum thickness of 20-25 microns.
- 9.PVDF 2 Coating - To approved colour to a minimum thickness of 80-100 Microns.

Aluminium composite panel shall consist of two aluminium sheets (A 3003 – H 16 or H 14) and antitoxic polythene. The thick of the aluminium sheet shall be 0.5 mm thick and antitoxic polythene 3 mm thick.

Aluminium composite panel shall be coated with PVDF coating kynar 500 in standard approved colour.

| **Product Range** | **Specification** |
|---|---|
| Aluminium composite panel | Thickness 3, 4 and 6 mm |
| Core | Antitoxic polythene |
| Width | 1020 mm<br>1250 mm<br>1575 mm |
| Length | Max. 8000 mm |

**Brush Bond**

Surface should be cleaned from oil, grease, wax, dirt and any other foreign material spelled and deeply disintegrated concrete should be removed to sound concrete and repaired. This has 2 components, brush bond powder and NITO bond BB acrylic emulsion.

Then the NITO bond BB is poured into a plastic or metal drum to this an equal volume of clean water is added. Then mixing is started with a slow speed drill (350 –450 RPM). The powder component is added gradually to the liquid avoiding lump formation and mixed for 2.3min, Mix and use, do not mix none material.

Then the material will be applied on the surface by mixing a short, stiff bristle brush, preferably 100 to 150mm wide. Apply with a paint in 2 coats

**Cinder Concrete Filling**

General: This specification covers the requirement for filling under flooring of toilets, balconies etc. This shall generally conform to the specifications No.TS.3

Materials: Cinders shall be obtained form furnace of steam boilers using coal fuel only. It shall be cleaned and free from clay dirt, wood ashes or other deleterious matter. It shall be 12.5mm nominal size i.e. passing through IS sieve designation 22 micron and 70 to 90 percent retained on IS sieve designation 106 micron. Cinder obtained from brick kiln shall not be used.

Preparation of Mix: Cement and cinder shall be measured separately by volume in the ratio of 1:15 unless otherwise stipulated in the description of the item. Cement used need not however be actually measured but a bag of cement of 50 Kgs shall be taken as equivalent to 0.35 cum in ingredients shall then be thoroughly mixed together so that the

cinders are uniformly and completely with neat cement.

Laying: The top surface of the roof slab shall be thoroughly cleaned of all dust, dirt and other foreign matte. The cinder concrete shall then be laid and spread on the area to the required slope and well rammed with wooden therapies to give a uniform sponge concrete, correct to slopes and levels.

Curing: The finished surface shall be cured for at least 7 days. During this period it shall be protected from sun, rain and other damage.

**Section-10**

# CIVIL & STRUCTURE

## Excavation and Earth Works

Excavation shall include careful removal of all materials or whatever nature and whether dry or wet, necessary for the construction of work, exactly in accordance with lines, levels, grades and curves shown on the plans
The bottom of the foundation shall be levelled both longitudinally and transversally or stepped as directed. Should any of the excavation be carried down to a level below the specified level.

### The excavation shall be carried out in accordance with the dimensions shown in the sanctioned drawings.

Any obstacle encountered during excavation shall be reported immediately to the Engineer-in-charge and shall be dealt with as instructed by him. Removal of buried piping or cables shall not be done without prior permission of the Engineer-in-charge and the contractor shall take all measures to protect such lines. Cost of such protective measures and deemed to be included in the rates for various items of excavation. No blasting shall be permitted for excavation of foundation even in rocky formation without the prior permission of the Engineer-in-charge
The contractor shall provide suitable drainage arrangements, to prevent surface water from any source entering the foundation pits, at his own cost.
The contractor shall not undertake any concreting in foundation until the excavation pits is approved by the Engineer-in-charge.
If the soil is soft, loose or slushy the trench shall be widened for allowing berms on either sides or the sides sloped or shored up. During excavation if rocks or rocky soils are found, (if approved as suitable for foundation), those shall be leveled as far as possible and the small spaces which are difficult to level shall be filled in with Controlled Low Strength Material (CLSM).

### Backfill Material.

Foundation trenches, column bases and the like shall be backfilled with selected excavated materials as described for imported fill, if approved by the Engineer.
Filling shall be done after the concrete or masonry in the foundation has fully set and its curing completed. It shall be done in such a manner as not to cause undue thrust on any part of the structure.
Back filling around completed foundations shall be done to the lines and levels shown on the drawings, including any trimming of the surfaces, as may be necessary. This will be done with selected and approved earth from excavation or otherwise with borrowed materials as directed by the Engineer-in-charge. Where sufficient suitable material is not available from the excavation, The Engineer-in-charge may direct to import suitable earth from different sources. The refilling shall be done in horizontal layers of thickness not exceeding 15cms from pocket with careful watering, ramming and rolling etc., to obtain necessary level of compaction.

### Imported Fill

Imported fill shall be selected, graded, hard, granular fill, free from clay and deleterious matter, with 100% free of stones larger than 75mm, upto 50% passing a 5mm mesh sieve and not more than 20% passing a 75micron sieve. It shall contain less than 0.2% total sulphates and less than 1.0gm per liter of water-soluble sulphates in a 2:1 water soil extract. Total soluble salts shall not exceed 2%

### Anti Termite Treatment

Area should be cleaned before application and the treatment should be done as per the contractual specifications/ IS code. Saturation of the soil with the chemical emulsion to be ensured.
Treatment along outside of foundations: The soil in contact with the external wall of the building shall be treated with chemical emulsion at the rate of 7.5 l/m2 of vertical surface of the sub-structure to a depth of 300 mm. To facilitate this treatment, a shallow channel shall be excavated along and close to the wall face. The chemical emulsion shall be directed towards the wall at 1.75 l/m of the channel. Roding with 12 mm diameter mild steel rods at 150 mm apart shall be done in the channel. If necessary, for uniform dispersal of the chemical to 300 mm depth from the ground level. The balance chemical of 0.5 l/m shall then be used to treat the backfill earth as it is returned to the channel directing the spray towards the wall surface.

## RCC/PCC works

### Cement

The cement material used shall comply with relevant codes as specified in IS 456-2000. Bags of cement shall be stored in a waterproof store with a raised floor. The cement shall be used in the order in which it arrives at site. Additives shall not be permitted without the consent of the Engineer. Samples of cement to be used in the works shall be approved by the engineer and samples shall be provided for approval before delivery of materials to site.

### Aggregate

Aggregates used in the construction shall comply with the requirements of IS 383:2016, "Coarse and Fine Aggregates for Concrete – Specification

### Coarse Aggregate

As far as possible, preference shall be given to natural aggregates, such as crushed stone, gravel, and sand, which meet the requirements of IS 383.

Recycled aggregates shall be used in accordance with the guidelines and norms specified by:

- Green Rating for Integrated Habitat Assessment (GRIHA)
- Indian Green Building Council (IGBC)

The use of recycled aggregates shall be subject to the approval of the Engineer and shall meet the requirements of IS 383. The nominal size of the graded aggregate shall be 20 mm to 5 mm or as specified.

### Fine Aggregate

As far as possible, preference shall be given to natural fine aggregates, such as river sand, quarry dust, or other naturally occurring materials that meet the requirements of IS 383.

Aggregates shall be stored on clean, self-drained concreted or paved areas with adequate division walls to prevent contact between different grades or types of aggregate. Graded aggregates, which have segregated in stockpiles, must be thoroughly mixed before use.

### Water

Water used for mixing and curing shall be clean and free from injurious amounts of oils. acids, alkalis, salts, sugar, organic materials or other substances that may be deleterious to concrete or steel. Potable water/RO water is generally considered satisfactory for mixing and curing concrete

### Admixtures

Admixture. if used shall comply with the requirements of IS 9103:1999, "Specifications for Concrete Admixtures

The workability, compressive strength and the slump loss of concrete with and without the use of admixtures shall be established during the trial mixes before use of admixtures

Approval: The use of admixtures shall be subject to the approval of the Engineer, based on the results of the trial mixes.

Quality Requirements: Admixtures shall meet the following quality requirements:

- Chemical Composition: The chemical composition of the admixture shall be as specified in IS 9103.
- Physical Properties: The physical properties of the admixture, such as density and viscosity, shall be as specified in IS 9103.

### Reinforcement

The reinforcement shall be of Mild steel and medium steel wire, conforming to I.S. 432-1960 or TMT bars conforming to I.S. 1786-2008 or deformed steel bars conforming to I.S.1139 with up-to-date modification.

Epoxy coated reinforcement where specified shall be fusion bonded conforming to ASTM A775.

Bars shall be bent cold by machine or other approved means. Reinforcement shall be accurately positioned and rigidly supported and tied with binding wire to prevent displacement during the concreting.

Bar bending schedules shall be prepared by the Contractor in accordance with the drawings and BS 4466 at least fourteen days in advance of any bending of reinforcement, and they shall be approved by the Engineer before any bars are cut or bent. Bars once bent shall not be straightened or rebent. Heating or welding of the reinforcement will not permitted unless the prior consent of the Engineer has been obtained in writing.

Reinforcement shall not be stored in contact with the ground.

### Mixes and Mixing of Concrete

Unless otherwise specified concrete in various locations shall be as follows:

| Usage | Concrete Class | Min. Cement Content | Max. W/C Ratio |
|---|---|---|---|
| Reinforced cement concrete in all locations | 20N/mm2 | 330 | 0.5 |
| Plain cement concrete in floors and pacing and other situations not covered under above | 20N/mm2 | 330 | 0.5 |
| Binding Concrete | 1:3:6 | 220 | 0.55 |

| | | | |
|---|---|---|---|
| Plain cement concrete 1:2:4 for underground piping benching and similar | 1:2:4 | 330 | 0.55 |

Where the concrete is specified to give strength more than mentioned above, the concrete shall be designed and tested according to IS 516 or to other approved standard to the full satisfaction of the Engineer.
The slump test shall be used as a guide to the workability of the mixed concrete, which shall be carried out by using a slump cone in accordance with IS 1199: 1959 "Methods of Sampling and Testing of Concrete"
The Engineer's approval to the Contractor's proposals for concrete proportions in no way relieves the Contractor of his responsibility for providing concrete of the minimum strength required.
Concrete shall be mixed in an approved Ready Mix Concreting (RMC) Batching Plant. The Volume of Mix shall be as per approved Mis Design Report.
The provisions of IS 4926 will govern the supply and use of ready mixed concrete.

### Sampling and Strength of Designed Concrete Mix

Samples from fresh concrete shall be taken as per IS 1199 and cubes shall be made, cured and tested at 28 days in accordance with IS 516
Adequate number of cube moulds along with slump cone shall be placed at work site. The samples shall be taken in accordance with relevant BIS/ technical specifications. As per clause 15.2.2 of IS:456, the frequency of sampling shall be as follows:

| **Quantity of Concrete (cum)** | **No. of samples** |
|---|---|
| 1-5 | 1 |
| 6-15 | 2 |
| 16-30 | 3 |
| 31-50 | 4 |
| 50 & above | 4+1 additional sample for each additional 50 cum or part thereof |

Freshly laid concrete shall be protected from rain. After about two hours of laying, when concrete has begun, to harden, it shall be kept damp by covering with wet gunny bags for 24 hours and7 days continuously. If specified curing may be done by covering concrete with special type of waterproof paper so as to prevent water escaping or evaporating.

### SLUMP TEST

The Contractor shall keep at the site of the works for the constant use of the Consultant's representative a standard slump test mold and shall provide facilities throughout the construction for tests to be made as and when the Client may require. The slump cannot be definitely stated until tests have been made using the materials adopted for the work, but it is anticipated, that the slump of between 25mm to 50mm will be required.
The Contractor at his own expense shall establish a field laboratory to carry out all preliminary tests, work tests and also to work out grading and proportioning of aggregates in order to obtain and maintain uniform quality of work. A 150 mm cube testing machine shall be installed by the contractor at his own expense to ascertain the strength of concrete from time to time. The contractor shall supply all materials, labour and testing machines for preparing and testing sample as required by the Engineer. The concrete shall also be got tested in an independent laboratory approved by the Engineer at the discretion of the Engineer or his authorized representative at no extra cost.

### TRANSPORTING PLACING AND COMPACTION OF CONCRETE

The concrete shall be transported maintaining required workability in a manner such as to avoid the segregation of the constituent materials, and loss of any of the ingredients. It shall be deposited as nearly as practicable in its final position to avoid re-handling. It shall be placed and compacted before setting commences and should not be subsequently disturbed. Methods of pouring should be such as to preclude segregation, and to avoid displacement of reinforcement and movement of formwork.
The concrete should be thoroughly compacted and fully worked around the reinforcement, around embedded fixtures and into the corner of the formwork without formation of honey combing, pinholes or surface irregularities and any other defects whatsoever. The use of mechanical vibrators having capacity of producing vibrations at a rate not less than 5000 cycles per minute is recommended. Over vibration or vibration of very wet concrete is harmful and should be avoided; under vibration is also harmful. In addition to mechanical vibration, sufficient hand tools must be used to ensure full consolidation around reinforcement and at edges and corners.
The deposition of concrete shall be carried out as continuously as possible to reduce to a minimum joint between new concrete which has set. Where construction joints are necessary, they shall be formed at right angles to the axis of the member concerned by the insertion of rigid stopping off form, against which concrete can be properly rammed.

Concrete shall not be dropped from a height of more than 1.0 M. No unset concrete shall be brought into contact with unset concrete containing cement of different type. Special permission and instructions shall be obtained when concrete has to be deposited under water. Under water concreting shall be done with the help of tremi pipe line only. Concrete shall contain 10% more cement than that required for the specific mix placed in dry condition.

Accumulation of set concrete on the reinforcement shall be avoided. Before fresh concrete is deposited upon or against any concrete which has already hardened, the surface of hardened concrete shall be well roughened, if necessary, by chipping and all Latinate removed. The surface shall then be swept clean with wire brushes, thoroughly wetted and covered with a thin layer of cement mortar.

Care should be taken such that there are no cold joints while laying concrete.

Use of Vibrators:

a. Immersion vibrator shall be inserted vertically at points not more that 450mm apart and withdrawn when air bubble seizes to come to the surface. Immersion vibrator shall be withdrawn slowly.

b. The immersion vibrator shall penetrate the layer being placed and also penetrate the layer below while the under layer is still plastic to ensure good bond and homogeneity between the two layers and prevent the formation of cold joints.

c. The use of surface vibrators will not be permitted under normal conditions. However, for thin slabs, such as highways, runways and similar constructions, surface vibration by specially designed vibrators may be permitted upon approval of engineer.

## Shuttering/ Formwork for Concreting

Formwork, centering, and shuttering should be constructed with materials that effectively prevent grout leakage and absorption of water from the concrete. It is recommended to use mild steel (MS) sheets as required, adhering fully to the standard specifications outlined in IS 1200 Part V. These measures shall be undertaken prior to laying the concrete to ensure confinement, support, and the maintenance of the concrete's position.

The design of formwork shall be per IS 14687:1999 "Formwork for Concrete - Code of Practice"

The following upward cambers are suggested to the formwork

i. Cantilevered slabs - 3 mm to every 1.5m of span

ii. Cantilevered beams - 6 mm to every 1.5m of span

iii. Slabs over 3m span - 3 mm to every 3.0m of span

iv) Beams over 6m span - 6 mm to every 3.0m of span but not exceeding 40mm.

### Removal of formwork

The removal of formwork is governed by IS 456:2000, which specifies the guidelines for the removal of formwork for different types of concrete elements

The formwork shall be removed avoiding shock or vibration that may cause any damage to concrete.

Formwork shall be removed only when concrete reaches the strength to withstand various loads while striking as per above IS codes.

| **Type of Formwork** | **Stripping time** |
|---|---|
| Vertical formwork to walls, columns, beams | 16-24 hours |
| Soffit formwork to slab (props to be re-fixed immediately after removal of forms | 3 days |
| Soffit formwork to beams (props to be re-fixed immediately after removal of forms) | 7 days |

## Expansion Joints

Expansion joints to be provided as per guidelines and according to IS 3414. Unless otherwise specified, the expansion joint filler shall be a 20mm thick bituminous board, subject to approval.

Sealant : The expansion joint shall be pointed with a 2-part polysulphide sealant, conforming relevant IS , to a minimum depth of 20mm.

## Wall Ties

Unless otherwise specified wall ties shall be zinc coated, 3mm mild steel fish tail type, 300mm long to comply with the requirements of IS 4326:.

## Vapour Barrier

Vapour barriers shall be polythene and shall consist of 1000 micron approved hydro-carbon thermoplastic resin or equivalent obtained from an approved manufacturer.

## Internal Civil Finishing Works

### Brickwork

The following I.S. apply to this section:

| I.S. NO. | SUBJECT |
|---|---|
| 1077-1992 (R2002) | Common burnt clay building bricks |
| IS: 1200 (Part-III) – 1976 | Methods of measurement of Brick works |
| IS: 2212 – 1991 | Code of practice for brick work |
| IS: 3495 (Part I to IV) 1992 (R2002) | Methods of tests on burnt clay building bricks |

Classification of bricks and dimensions

Bricks shall be classified on the basis of their minimum compressive strength as given below :

| Class Designation | Average compressive strength | |
|---|---|---|
| | Not less than (N/mm2) | Less than (N/mm2) |
| **12.5** | 12.5 | 15 |
| **10** | 10 | 12.5 |
| **7.5** | 7.5 | 10 |
| **5** | 5 | 7.5 |
| **3.5** | 3.5 | 5 |

The brick may be modular or non-modular.

| Type of Bricks | Nominal Size mm | Actual Size mm |
|---|---|---|
| **Modular** | 200 x 100 x100 | 190 x 90 x90 |
| **Non Modular** | 230 x 115 x75 | 225 x 110 x 70 |

The selection of bricks shall be done as per the requirement and specifications of the work. The quality of clay bricks, Fly ash bricks & Solid concrete blocks & other masonry units shall be as per relevant IS standards bricks shall be soaked well in water for at least 1 hour prior to use and will be in surface dry condition at the time of lying.

Cement mortar as specified, shall be made with fine natural sand and specified Portland cement.

### Block Masonry

Precast concrete blocks shall comply with the requirements of IS 2185 (Part 1 to Part 3):2005. The materials used for the manufacture of blocks (i.e. cement, aggregates and water) shall comply with the relevant clauses as specified in "Concrete Masonry Units - Specification".

Precast concrete blocks shall be made in approved block making machines in the thickness required. The materials for all blocks shall be mixed upon a clean mixing platform or in an approved mechanical mixer and shall be gauged with sufficient water to enable the materials to bind together under pressure and thereafter placed in the block making machine in layers not exceeding 75mm, each layer being thoroughly tamped or, if approved, machine vibrated.

Types of blocks to be used are as follows:

Minimum Compressive Strength – as per IS: 2185 (Part I & II)

Size of Block(mm)

Length : 400, 500 or 600 mm

Height : 200 or 100 mm

Width : 50,75, 100, 150,200, 2500r300 mm

- Non-Load Bearing Walls : Not less than 3.5 N/mm2
- Load Bearing Walls : Not less than 7.0 N/mm2

Blocks may solid or hollow for load bearing walls but they must be solid below plinth level.Blocks Made from natural and recycled materials like Cement, lime, sand, water, lime, Gypsum and an expansion agent like aluminum powder CAN BE USED in accordance with the guidelines and norms specified by:

- Green Rating for Integrated Habitat Assessment (GRIHA)
- Indian Green Building Council (IGBC)

Testing of Blocks

Testing of blocks shall be in accordance with IS: 2185: Part I

### Mortar

Cement and water for mortar shall be as specified for "concrete work"

Sand for mortar to be natural sand, crushed stone, or crushed wadi gravel conforming to the requirements of IS 383:2016.

### Plastering

The thickness of plastering shall be minimum 12 mm (1/2") with appropriate rendering as per IS 2402- 1963.

### Flooring, Dadoing and Skirting Works

Flooring with ceramic and vitrified tiles

The tiles shall be of approved quality, shape, size, color and free from any deformities, and shall comply to IS 13630 (Part 1 to Part 4):2014

The tiles shall be tested for its mechanical properties such as strength and hardness prior to usage and stacked in an enclosed space properly as per manufacturer's instructions.

## Granite/ marble works

The tiles shall be of approved quality, shape, size, color and free from any deformities, and shall comply to IS 3316:1974

- The marble/granite stone should satisfy the following requirements:
- The stone should be hard, even, sound and durable.
- The slabs should be of uniform color, free from stains, cracks, decay and weathering.
- The slabs shall be sawn or cut in plane parallel to the natural bed of the slope.
- They shall be cut in perfect line; and right angles should be maintained.
- They shall be uniform in size and the edges shall be truly square.

## IPS Flooring

The Concrete Flooring shall be carried out in accordance with IS 2571- 1970. The workmanship shall comply with IS 3025:1983

- The sub base shall be of sand, PCC
- If the base surface is Cement concrete shall be placed in position and beaten with trowel till the surface is found covered with cream of mortar.

## Vacuum Dewatered Concrete Flooring

Concrete is poured in place and vibrated with a poker vibrator.

## Polished Slab Granite flooring

Polished granite slab shall be machine cut. Machine cut slabs shall have fine tooled dressing on all sides to full depth. Slabs shall be washed clean before laying. The bedding mortar of the specified mix shall be spread under each slab, slab shall be then laid on top, pressed so that the hollows underneath get filled and surplus mortar works up through the joints. The slabs should be tapped with wooden mallet and brought to level and close to adjoining slabs with thickness of joints not exceeding 1.5 mm. After laying each slab surplus mortar on the surface of the slabs shall be cleaned off and joint finished flush. Subsequent slabs shall be laid in the same manner. The joint shall be left raked out uniformly to a depth not less than 10 mm, when the mortar is still green. The surface of the flooring laid, shall be true to levels as directed by the Engineer-in-Charge. Slabs, which are fixed in the floor and joints the wall not less than 12 mm under the plaster, and floor shall be finished neatly and without waviness.

The flooring shall be cured for Fourteen days. The finished floor shall not sound hollow when tapped with wooden mallet. Measurement shall be on Sq. mt. basis. The rate shall include cost of all materials, labour and shuttering involved in all the operations.

### Glazed Earthenware/Tiles/Ceramic Tile Flooring, Dado and Skirting

Glazed earthenware tile shall conform to I.S. 777-1970, specification for glazed earthenware tiles. When fractured they shall appear fine grained in texture, dense and homogeneous. The tile shall be flat true to shape, sound and free from flaws and other manufacturing defects.

Facial dimensions: The length of all the four sides of tiles shall be measured to the nearest 0.1 mm. The average value shall not vary more than + or – 0.8 mm from the dimension of the nominal size. The variation of the individual dimension from the average value shall not exceed + or – 0.5 mm.

Tolerance on thickness + or – 0.5 mm.

Water absorption: The average water absorption of the tile when tested and evaluated shall exceed 18 percent.

Impact strength: Tiles when tested for impact strength shall not have a value less than 0.020 Kg fm/cm.

Bedding over which the glaze tiles shall be laid as indicated and shall not be less than 10 mm at any place. Mix of bedding layer should be as specified. Tiles shall be soaked in water before laying.

Base shall be cleaned and wetted. The bedding shall then be laid evenly over the surface, tamped and corrected to desired levels and allow to harden enough to offer a rigid cushion to tiles. Before laying the tiles, cement slurry of honey like consistency 3 Kg /Sq. mt. shall be applied over the bedding. At a time, area to accommodate about 20 tiles shall be applied with cement slurry. Tiles shall then the washed clean and fixed in the grout one after the other. Each tile being gently tapped in its position till it is properly bedded and in level and line with adjoining tiles. The joint shall be as thin as possible but not exceeding 1.5 mm wide.

In the case of skirting and dado, the wall surface shall be covered with about 10 mm thick plaster of cement and sand mortar 1:3 and allow to harden. The plaster shall be roughened with wire brushes or by scratching diagonal lines. The back of the tiles shall be buttered with cement paste and set on bedding mortar. The tiles shall be gently tapped in position one after the other. Top of skirting or dado shall be truly horizontal and the joints vertical or as per required pattern.

The joints shall be racked to a depth of 5 mm and all dust and loose mortar removed. Joints shall then be flush pointed in White cement or in coloured cement in the case of coloured tiles. The surface shall be cured for seven days and then wash clean.

Mode of Measurement: Payment will be on Sq. mt. basis. Rate shall include cost of all materials labour and shuttering involved in all the operations.

## Painting

The following I.S. apply to this section;

| I.S. NO. | SUBJECT |
|---|---|
| 5410-1969 | Specification for cement paint,colour as required. |
| 2932-1974 | Enamel, synthetic, exterior, under coating and finishing (First Revision) |

## CEMENT PAINT

Cement paint shall comply with I.S. 5410-1969, specification for cement paint, colour as required. The material shall be in powder form, free from lumps that are not friable and when mixed with required volume of water shall be suitable for use on porous surface of masonry, concrete and rough plaster work.

## PAINTING WOOD WORK

Paint shall comply with IS 3915:1984.All wood work shall be dried free from dust, dirt or any extraneous materials. Flat portion shall be smoothened with abrasive paper used across the grain prior to painting. All loose knots removed, and holes filled.

PAINTING STEEL AND IRON WORK

- Paint shall comply with IS 1573:1993
- The surface shall be thoroughly cleaned of dirt, fluxing material, other foreign material .
- Temporary rust protective materials applied to steel sheets to protect during transport and storage shall be removed with suitable solvent as a preliminary to other preparatory treatment.
- Surfaces already pretreated or primed in a factory shall be carefully inspected and damage areas shall be thoroughly degreased and cleaned of all dust and touch up.
- Priming coat shall be applied by brush, working in the paint into the fine dents and ensuring a continuous film without runs and holds.
- After the primer coat is harden and dry, Deep dents and scratches, if any shall be filled with paste
- Under coating shall be applied by brush. The film shall be allowed to hard dry, wet rubbed and cut down to a smooth finish ensuring that at no place under coat is completely removed.
- Finishing coat shall be applied for brush. Special care shall be taken while painting over bolts, nuts, rivets and overlaps etc.
- The painted surfaces shall present a uniform appearance and from streaks, blisters etc.

## Flush Door Shutters

Flush door shutters shall be solid core type with block board coat, as indicated, and shall conform to I.S. 2202 (Part I) – 1983, specification for wooden flush door shutters (solid core type) Part-I plywood face panels. Except with regard to the sizes of shutter which shall be as indicated. Flush door shutter shall be non-decorative (commercial) type. Flush door shutters internally lipped, internal lipping may be provided separately or as one piece with the frame. The width of frame including lipping shall not be less 50 mm. Where separate lipping is specially desired, it shall be

as indicated. Internal lipping shall have total depth of not less than 25 mm, joints shall not be permitted in lipping.
In the case of doubled leaved shutters, rebating shall be splayed or square as directed. Where separate lipping is indicated the depth of lipping at the meeting of stiles shall not be less than 35 mm.
Flush door shall be free from twist, or warp in plane and all the four edges of the door shutters shall be square. Both the faces of the door shutter shall be sanded to a smooth even texture.
Tolerance on nominal thickness shall be + or – 1.2 mm. Thickness of shutter shall be uniform through the variation not exceeding + or – 0.8 mm when measured at any two points.

Fibre Glass Reinforced Plastic (F.R.P) Shutters

F.R.P shutters shall be manufactured conforming to the specification as per IS 14856 and nomenclature of item and direction of Engineer in charge.
Blocks of any seasoned hardwood of bulk density not less than 450 kg/3 at 12 percent moisture content or any other material of sufficient thickness and length shall be provided inside the shutter at suitable place to hold fittings and fixtures such as aldrops, tower bolt, handle, sliding door bolt, mortice lock etc. blocks for hinges shall be provided at predetermined places in the shutter so as to fix hinges mortice locks, tower bolts, aldrops, door closures, etc. The finished surfaces shall be buffed and polished with wax.

Stainless Steel Work

The stainless steel railing pipes, hardware's & accessories of specified grade to be supplied and installed at site as per the above mentioned specifications as per BOQ, drawings and approved by the Engineer – in – charge.
The material properties of stainless steel pipes and accessories should be confirming to SS 304 grade.
The stainless steel pipes shall be procured from approved manufacture and of approved grade. The quality stainless steel sheet and pipe shall be approved by client / consultant before proceeding with execution any item of work.
The pipe used for handrail shall be of 16 gauge thick. The welded links are to be ground and organ buffed to get the original finish of the surface of the material welded. The joints or junctions where two pieces are joined / welded to be precisely cut and then welded.

## Structural Glazing

Scope includes design and execution of the work of providing semi unitized structural glazing with all the accessories such as extruded aluminum frames, aluminium composite panels, glass wool insulation, anchor clips, fasteners, brackets, gaskets, sealants, spacers, baker rods and related works perimeter flashing, continuous gutter system at each floor of the glazing, performance test etc., complete.
IS 875 (Part 3) : Code of practice for Design loads for buildings and structures Part- 3 Wind loads
AS-1288 1984 : Glass in Building ASTMC 1036-85
BS 626 : Glazing
Glass Saint Gobain/ Pilkington/ Galverbel 6mm thick heat strengthened, hard coated (Bronze of tint) Reflective glass possessing the following parameters.

| SL.NO. | DESCRIPTION | DATA |
|---|---|---|
| 1 | • Light information<br>• Transmission<br>• Reflection Ext.<br>• Reflection Int. | •<br>• 27 %<br>• 17 %<br>• 23 % |
| 2 | UV | 6% |
| 3 | • Energy characteristics<br>• ER<br>• EA<br>• SF | •<br>• 10%<br>• 76%<br>• 0.24% |
| 4 | Shading co-efficient | 0.28 |
| 5 | U – Value | 2.76 |
| 6 | Relative heat gain | 216 watts/ M2 |

## Aluminum Composite Panels

Shall be from Alucobond or Renobond and thickness shall be 4mm. The colour to match with the colour existing Environments

- 1.Structure Silicone
- 2.Dow corning
- 3.DC 995 1 Part & DC 983 2 Parts
- 4.Aluminium Sections
- 5.Indal Co./ Jindal / Bhoruka
- 6.Conforming to IS 63400 t5 /16063. Alloy AIMg SI-05
- 7.Minimum thickness = 2mm
- 8.Anodization: Anodized to approved colour to minimum thickness of 20-25 microns.
- 9.PVDF 2 Coating - To approved colour to a minimum thickness of 80-100 Microns.

Aluminium composite panel shall consist of two aluminium sheets (A 3003 – H 16 or H 14) and antitoxic polythene. The thick of the aluminium sheet shall be 0.5 mm thick and antitoxic polythene 3 mm thick.
Aluminium composite panel shall be coated with PVDF coating kynar 500 in standard approved colour.

| Product Range | Specification |
|---|---|
| Aluminium composite panel | Thickness 3, 4 and 6 mm |
| Core | Antitoxic polythene |
| Width | 1020 mm<br>1250 mm<br>1575 mm |
| Length | Max. 8000 mm |

Brush Bond

Surface should be cleaned from oil, grease, wax, dirt and any other foreign material spelled and deeply disintegrated concrete should be removed to sound concrete and repaired. This has 2 components, brush bond powder and NITO bond BB acrylic emulsion.
Then the NITO bond BB is poured into a plastic or metal drum to this an equal volume of clean water is added. Then mixing is started with a slow speed drill (350 –450 RPM). The powder component is added gradually to the liquid avoiding lump formation and mixed for 2.3min, Mix and use, do not mix none material.
Then the material will be applied on the surface by mixing a short, stiff bristle brush, preferably 100 to 150mm wide. Apply with a paint in 2 coats

## Cinder Concrete Filling

General: This specification covers the requirement for filling under flooring of toilets, balconies etc. This shall generally conform to the specifications No.TS.3
Materials: Cinders shall be obtained form furnace of steam boilers using coal fuel only. It shall be cleaned and free from clay dirt, wood ashes or other deleterious matter. It shall be 12.5mm nominal size i.e. passing through IS sieve designation 22 micron and 70 to 90 percent retained on IS sieve designation 106 micron. Cinder obtained from brick kiln shall not be used.
Preparation of Mix: Cement and cinder shall be measured separately by volume in the ratio of 1:15 unless otherwise stipulated in the description of the item. Cement used need not however be actually measured but a bag of cement of 50 Kgs shall be taken as equivalent to 0.35 cum in ingredients shall then be thoroughly mixed together so that the cinders are uniformly and completely with neat cement.
Laying: The top surface of the roof slab shall be thoroughly cleaned of all dust, dirt and other foreign matte. The cinder concrete shall then be laid and spread on the area to the required slope and well rammed with wooden therapies to give a uniform sponge concrete, correct to slopes and levels.
Curing: The finished surface shall be cured for at least 7 days. During this period it shall be protected from sun, rain and other damage.

**Underground Automatic Commercial Parking Lot**

1. The fully automatic underground commercial parking system shall be designed to maximize vehicle storage capacity in urban areas while minimizing land usage. The underground parking solution shall utilize automated lifts, shuttles, and storage systems to park and retrieve vehicles without human intervention,

ensuring fast, safe, and efficient operation. The design, construction, maintenance and operation shall conform to - NBC 2016 (Parking and Fire Safety); - IS 875 (Load calculations); - IS 456 (Concrete structures); - OSHA/EN Standards for automation and safety - MoHUA Urban Parking Guidelines- Electrical Standards: IS 732, IEC 61439.

2. Fully Automatic Underground Parking System shall be modular handling vehicles with independent access and retrieval using vertical lifts and horizontal shuttles.
3. Vehicle Accommodation shall be as follows

   Maximum Vehicle Dimensions:
   - Length: 5,200 mm
   - Width: 2,100 mm
   - Height: 1,750–2,000 mm (depending on vehicle type)
   - Maximum Weight: 2,500 kg
   - Vehicle Types Supported: Sedans, SUVs, EVs
4. Mechanical and Lifting System shall be lift Type: Hydraulic or electro-mechanical vertical lifts - Lifting Speed: 30–60 m/min; Horizontal Movement: Shuttle or Conveyor systems (speed 60–90 m/min); Turntables: Integrated turntables for vehicle orientation (if required); Platform Structure: Galvanized steel platforms with anti-skid coating, Structural Load: Up to 3 tons per parking module.
5. Electrical and Control System shall be provided with PLC/SCADA based automation
   RFID/Card user interface, OTP, Touchscreen, or Mobile App; Display shall be Digital indicators for operation and vehicle status; voltage: 415V, 3-phase AC, 50 Hz; Power Backup UPS for control; DG set or BESS for full operation
   Energy Optimization: shall be done through smart load distribution and power factor correction.
6. Safety and Security - Fire Protection: Integrated fire detection, alarm, and suppression (sprinkler, gas-based, etc.); - Safety Locks: Mechanical and electro-magnetic safety locks at each level; - Sensors: Obstacle detection, vehicle presence, and overloading sensors; Emergency Exits: Per fire and building codes
   CCTV real-time monitoring with night vision and cloud storage
   - Access Control: Biometric, RFID, or app-based entry for authorized users only.
7. Basement RCC walls and slabs shall be treated with waterproofing
   treatment; sump pit will be provided with automatic dewatering pump
   Mechanical exhaust with CO sensors and emergency fans;
   150 lux average lighting shall be provided with emergency lighting
   Structures shall be seismic resistant as per IS 1893 (Zone-specific design).

**Compliance and Standards**

- NBC 2016 (Parking and Fire Safety)
- IS 875 (Load calculations)
- IS 456 (Concrete structures)
- OSHA/EN Standards for automation and safety
- MoHUA Urban Parking Guidelines
- Electrical Standards: IS 732, IEC 61439

**Operation and Maintenance**

- Annual Maintenance Contract: Required with 24x7 support
- Training: Operator and emergency crew training provided
- Remote Monitoring: Centralized cloud-based diagnostics and alerts
- Downtime: Retrieval time ≤ 120 seconds; system availability ≥ 98%a